2 Climate and Pedoclimate of Italy

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2.1 Introduction

Climate is a major driving force of pedogenesis, especially during the first stages of soil formation. Italian soils, often rejuvenated by water erosion, have a potential strong geographic correlation with climate. Climate also determines vegetation cover and crop diffusion and management, which in turn influence the soil development. On the other hand, accelerated erosion and mass movements, triggered by relief and tectonic, as well as the deep and long-lasting impact of man in Italy, tend to homogenize soil profile and decrease pedodiversity.

Italy is placed in the middle of the Mediterranean basin and at the same time of the temperate zone of the boreal hemisphere, but its climatic regimes are much variegated and contrasted (Fig. 2.1[1]).

Italy stretches with its elongated shape from the 36° (35° considering the island of Lampedusa) and the 47° parallels; therefore, Italian climates are first of all influenced by different amounts of radiation energy. Another important geographic factor of the country is its peninsular nature. The Mediterranean seas, which almost surround the country, are a reservoir of heat and humidity for the inland. However, not all seas have the same mitigating action: the Adriatic Sea, in particular, rather thin and shallow, shows a less pronounced effect than the Tyrrhenian Sea (Fig. 2.2[2]), which is much larger and deeper.

Orography plays another major role on Italian climates. Italy hosts the highest elevation of geographic Europe (Monte Bianco 4,810 m, Aosta Valley) and the tallest active volcano (Etna 3,343 m, Sicily). The Alps as a barrier not only exert an action with respect to the cold currents from the Arctic regions of Northern Europe, but also against the temperate, wet air masses which come from the North Atlantic, often originating a warm strong wind (foehn), which during winter may cause severe episodes of snow melting and blowing. In addition, the Alps, along with the Northern Apennines, surround a river basin, the Po Plain, subject to atmospheric subsidence, with air stagnation in the lower layers, pronounced summer warming and strong cooling in winter, enhancing continentality.

The Apennines and related relieves deeply influence also the Italian climates, intercepting the perturbations coming from the Atlantic Ocean at west, but also those coming from the northeast. Their rough morphology, in particular, causes sharp temperature variations along short distances, frequent rainfalls for adiabatic cooling and stau[3] wind currents, winter fog stagnation inside the several internal closed basins and narrow valleys.

2.2 Temperatures

The long-term mean annual air temperature (MAT) of the whole of Italy, 12.6 °C, reflects its position in the temperate zone (Table 2.1). Nevertheless, it spans about 30 °C, from several degrees below zero on the Alps to around 20 °C in some parts of Sicily, pointing to an exceptional climatic variability, if compared with the size of the country (Fig. 2.3[4]).

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[1] Google Earth view.

[2] ArcGlobe data.

[3] Ascent of moist air is responsible for the enhancement or formation of stau cloudiness along the mountain slope.

[4] The map was obtained using the regression kriging method (MLRA) to spatialize long-term mean annual temperature data (MAT) of 1,086 meteorological station. A linear model was defined in which mean annual temperature was related to elevation and latitude (adjusted R-squared: 0.6613, p value: <2.2e-16). The model was applied by means of a raster calculation (MLRA grid). MLRA prediction errors (difference between predicted and measured values) were then interpolated by ordinary kriging and subtracted from MLRA grid. Differences between legend classes are larger than standard errors.

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Fig. 2.1 Italy is placed in the heart of the Mediterranean basin and temperate zone of the boreal hemisphere

MAT higher than 14 °C is widespread all along the central–southern part of the country and is rather well related with the cultivation of the olive tree, one of the most typical and widespread Mediterranean crop.

The degree of continentality is another important characteristic of Italian climates. On a country average, summer temperature is warmer than winter more than 15 °C (Table 2.1). In particular, Fig. 2.4 shows the relatively high continentality of the Po Plain and related valleys, exceeding a difference of 17 °C between summer and winter. Figure 2.4[5] also indicates a decrease in continentality from north to south and from east to west, as a main consequence of the distance from the seas and of the different mitigating action of them. The city of Ancona, for instance, has a thermal excursion similar to that of Florence, although it lies close to the Adriatic Sea, while Florence is about 100 km far from the Tyrrhenian Sea. On the other hand, long-term meteorological data of cities placed along the coast of the Tyrrhenian Sea, like Naples, Cagliari and Palermo, demonstrate seasonal excursions of around 13 °C, or less.

2.3 Precipitations

The variability of mean total annual precipitations (MAP) is even more pronounced than temperatures. Table 2.1 reports a mean value that is typical of temperate regions, but the difference between maximum and minimum long-term values, more than 1,800 mm, and the large standard deviation highlight the presence of very dissimilar rainy conditions, which are depicted in Fig. 2.5[6]. The highest long-term values are recorded in the northeast of the country, in the Friuli region. Values exceeding 1,900 mm are also reported in an area between the Lombardy and Piedmont Alps, as well as in northern Tuscany (Apuane range), where the Apennines intercept the Atlantic perturbations, as well as the cyclones that form in the Gulf of Genoa. On the other hand, the absolute lowest long-term average annual precipitation is reported for an area southeast of Cagliari (around 400 mm), but territories with relatively low rainfall are widespread in the two main islands as well as in the Apulia and Basilicata regions. Also some

[5] The map was obtained with an ordinary kriging interpolation of the difference between summer and winter air temperature of 1,086 stations. Differences between legend classes are larger than standard errors.

[6] The simple kriging prediction map was obtained by interpolating the mean annual precipitation of 2,200 stations. Differences between legend classes are larger than the standard errors.

Fig. 2.2 Italy stretches from the 36° and the 47° parallels

areas of northern Italy have averages ranging from 400 and 700 mm, in particular, the easternmost part of the Po Plain, the Bolzano, and the inner part of Valle d'Aosta.

The snow cover is widespread during wintertime in the Alps, the Apennines and the highest relieves of the islands, but it can also reach the plains of northern and central Italy, especially along the Adriatic part of the country, in occasion of the irruptions of arctic cold winds. Significant amount of snow in plain, between 20 and 50 cm, is particularly frequent in northwestern Italy (Valle d'Aosta, Piedmont and Lombardy) and on the hills of Emilia-Romagna and Marche regions, where the snow pack lasts between 10 and 25 days per year. On the Western and Central Alps, the average snow depth at 1,500 m a.s.l. ranges from 100 to 230 cm, but it reaches 250–400 cm on the Eastern Alps. Therefore, the amount of water stored in the snow pack (SWE) is absolutely relevant and at 1,800 m a.s.l. in the Western Alps ranges between 250 and 500 mm. The average snow cover duration is 200 days or more, according to the elevation. On the Apennines instead snow pack is between 100 and 350 cm, on average, and the mantle generally persists no more than 100 days, apart from the highest peaks.

Table 2.1 Long-term values of characteristic climatic and pedoclimatic parameters for the whole Italian territory

Parameter	Mean	Min.	Max.	St. Dev.
Mean annual air temperature (°C)	12.6	−11.0	19.0	3.9
Potential evapotranspiration (mm)	1002.0	643.9	1,308.1	149.2
Mean total annual precipitation (mm)	932.5	434.4	2,254.1	286.7
Aridity index (P/ETo)	0.98	0.36	2.80	0.40
Fournier index (mm)	90.2	42.9	210.9	24.9
Continentality index (summer minus winter air temperature, °C)	15.1	13.2	17.1	0.9
Seasonality index (rainiest minus lowest rainy month, divided by total annual rainfall, %)	10.7	3.6	20.6	3.0
Soil aridity index (dry days per year)	70	0	148	31
Soil temperature at 50 cm depth (°C)	14.4	4.6	22.7	2.6

Values obtained from the raster spatialization reported

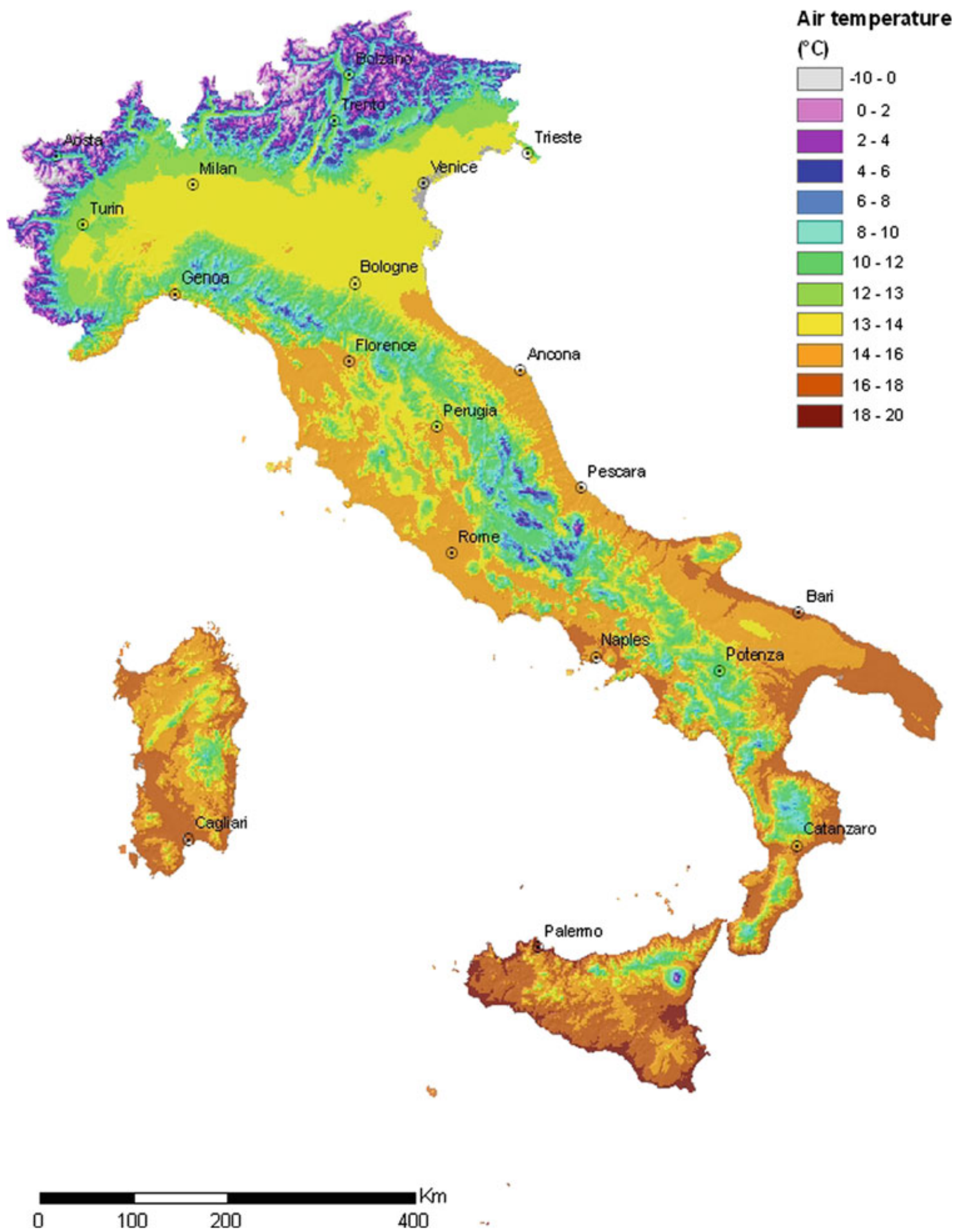


Fig. 2.3 Long-term mean annual air temperature (1960–2008)

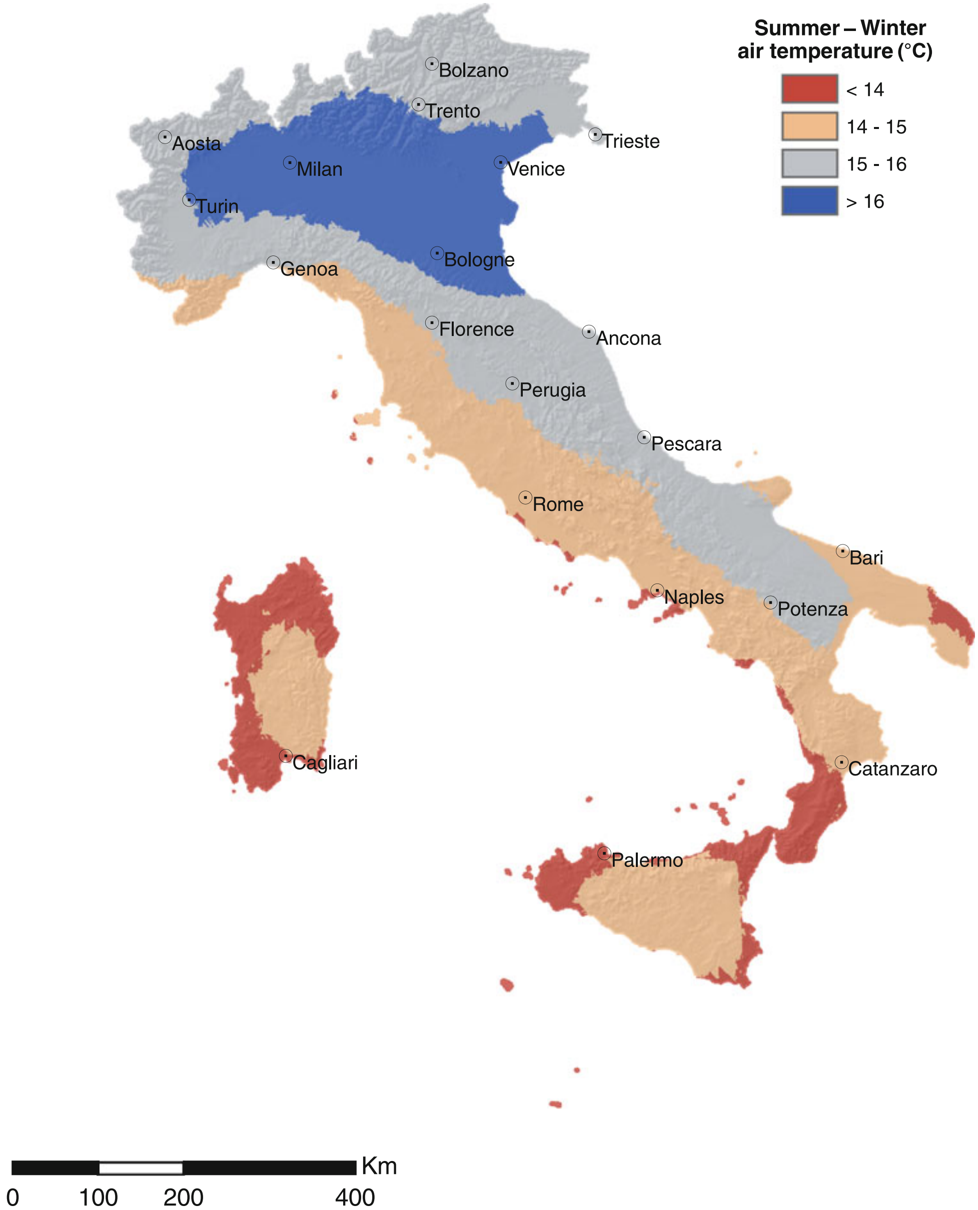


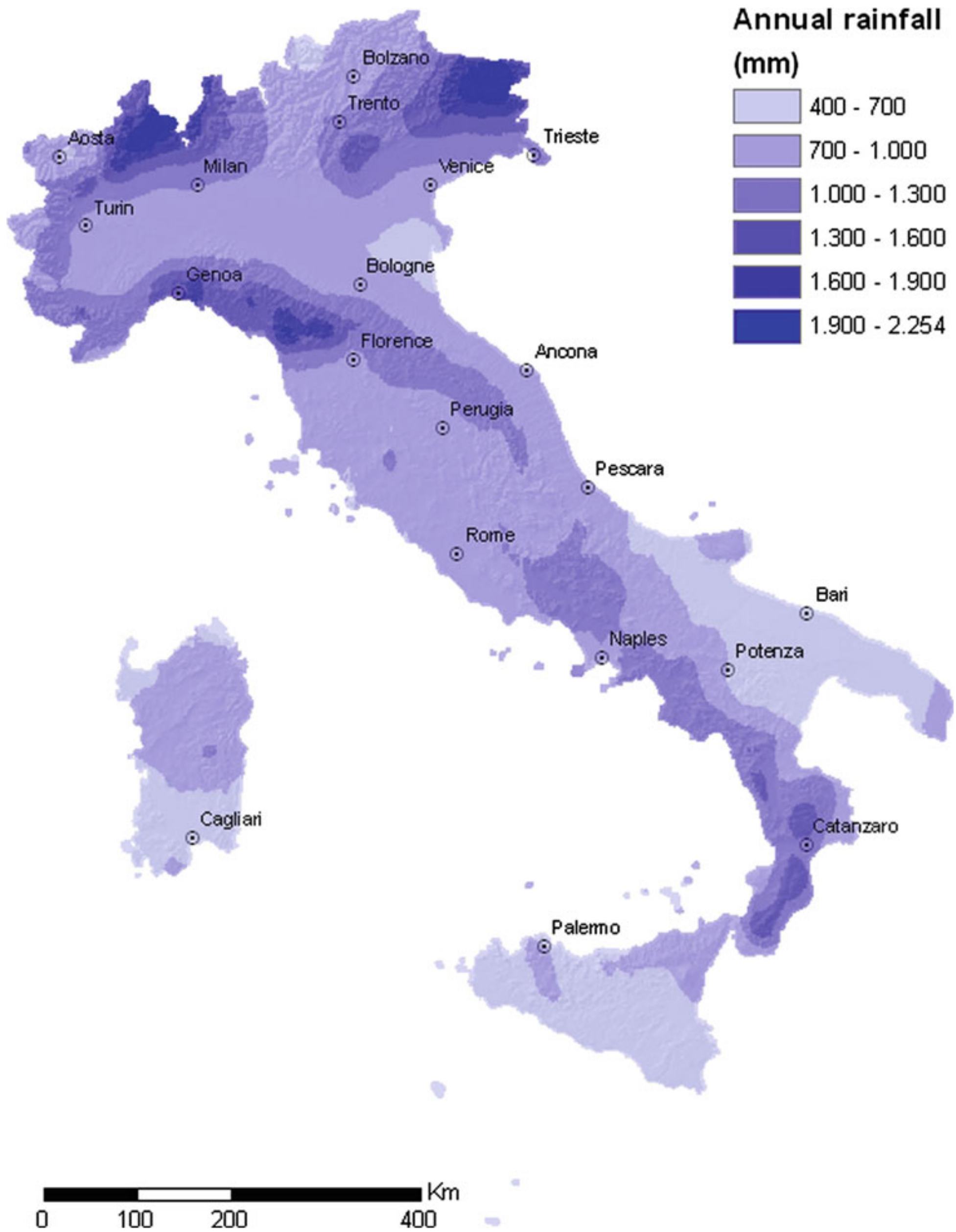
Fig. 2.4 Mean summer – winter air temperature (Continentality index) (1960–2008)

The average value of rainfall erosivity in Italy, expressed as Fournier index (Arnoldus 1977), highlights the high risk of erosion that threaten Italian soils (Table 2.1). The corresponding map (Fig. 2.6[7]) marks a distinction in the average values between the different parts of Italy, with a minimum of about 43 mm, in Apulia, and a maximum of more than 210 mm in Friuli, Tuscany, Campania and Calabria. The areas with the most concentrated precipitations partially coincide with the rainiest territories (Friuli, part of Lombardy and Piedmont, northern part of Tuscany), but they also extend to the coast of Liguria and the southern regions of Italy facing the Tyrrhenian Sea (Campania, Basilicata, Calabria). Other critical areas are located in Sicily, between the Etna Mountain and the Ionian Sea, and in eastern Sardinia, between the Gennargentu Mountain and the Tyrrhenian Sea. On the other hand, the plains and hills shadowed by mountain relieves against perturbations show the lowest long-term values of rainfall intensities (Po Plain, Apulia region, inner and southern parts of Sicily, southern Sardinia).

Precipitation seasonality, that is, the difference between the amount of long-term rainfall fallen in the most and in the least rainy months, proportioned to the total long-term annual rainfall, is on country average 11 % (Table 2.1). The index reflects the seasonality of the precipitations, which is another typical trait of Mediterranean climates. It is

[7] The ordinary kriging prediction map was obtained by interpolating the values of Fournier index of 1,546 meteorological stations. Differences between legend classes are larger than the standard errors.

Fig. 2.5 Long-term mean annual rainfall (1960–2008)



worthwhile to compare the map in Fig. 2.7[8] with that of continentality (Fig. 2.4). As a rule, areas with the most characterized features of Mediterranean climate may have a precipitation seasonality more than double than those with more continental climates, which show a more regularly distributed precipitation pattern. The northern, innermost part of the Alps makes exception, but it must be stressed here that, contrary to Mediterranean types of climate, the highest rainfall falls during summertime (see for instance the meteorological station of Faloria, Fig. 2.13).

2.4 Potential Evapotranspiration and Aridity Index

Mean long-term country value of potential evapotranspiration (ETo, Pennman Monteith, Allen et al. 1998) is 1,002 mm (Table 2.1), ranging from around the 600 mm in the Alps and the Northern Apennines to more than 1,300 mm of some parts of Apulia, Sicily and Sardinia

[8] The map was obtained by computation of raster datasets of mean summer, winter and annual precipitation. The rasters of mean summer and winter precipitation were the ordinary kriging prediction maps of 1,297 stations. Differences between legend classes are larger than the standard errors.

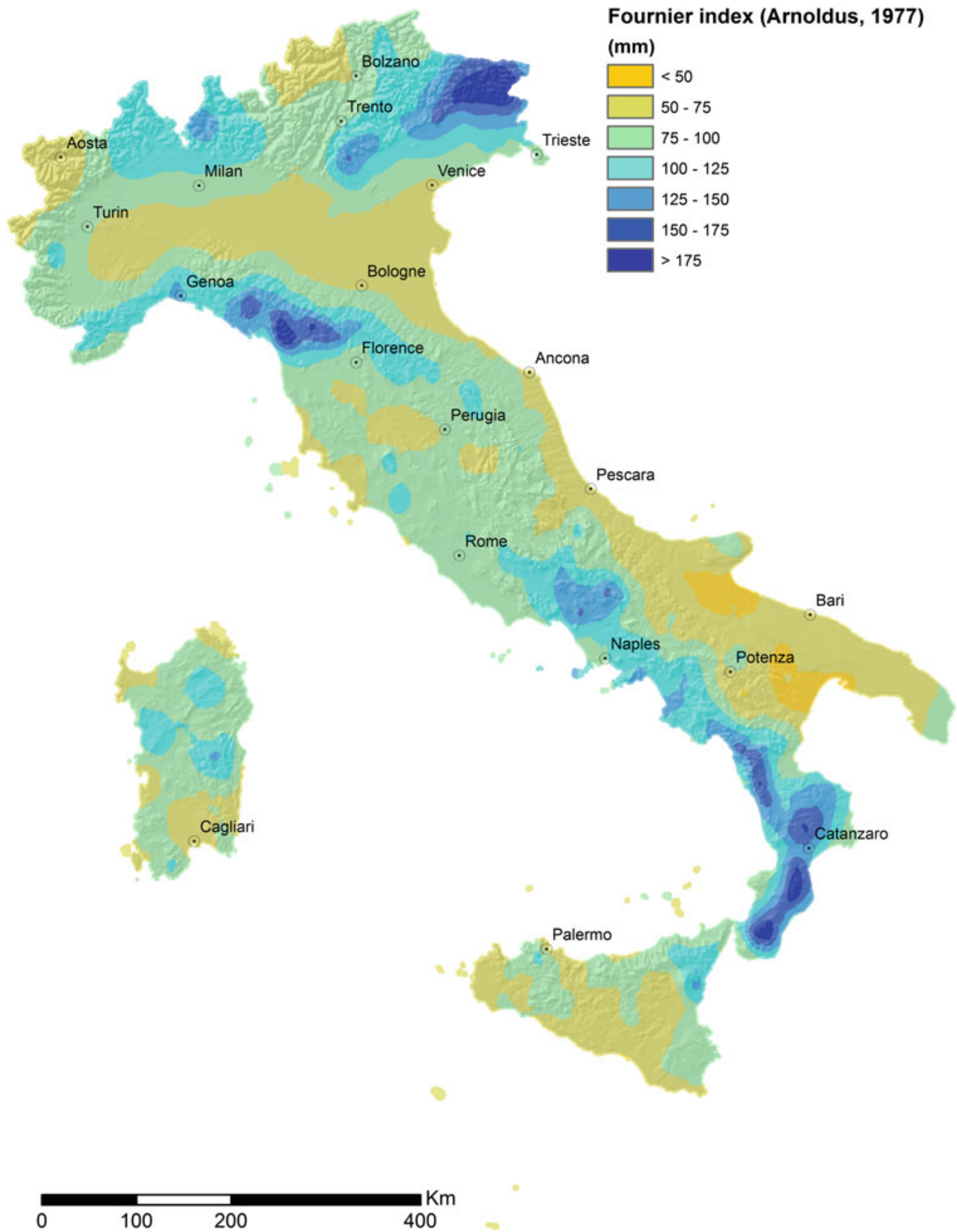


Fig. 2.6 Fournier index (1960–2008)

(Table 2.1 and Fig. 2.8[9]). Average values exceeding 1,000 mm are widespread in most parts of southern Italy and along the coasts of the Tyrrhenian Sea in central and northern Italy, up to the Liguria region.

Although the mean country value of annual precipitation is almost the same of potential evapotranspiration (Table 2.1), the climatic deficit, that is the ratio between rainfall and ETo (aridity index, UNEP 1992) less than one, dominates Italy (Fig. 2.9[10]). Lands where precipitation exceeds evapotranspiration are only located on the Alps, the northern part of the Po Plain and parts of the Apennines. On the other side, many territories of southern Italy are classified dry sub-humid or semiarid, especially in Sicily, Apulia, Sardinia and Basilicata.

[9] Mean values of 544 cells (ETo according to FAO Penman–Monteith; Perini et al. 2004). Differences between legend classes are larger than the standard errors.

[10] The map was obtained from the raster datasets of annual precipitation and potential evapotranspiration. Differences between legend classes are larger than the standard errors.

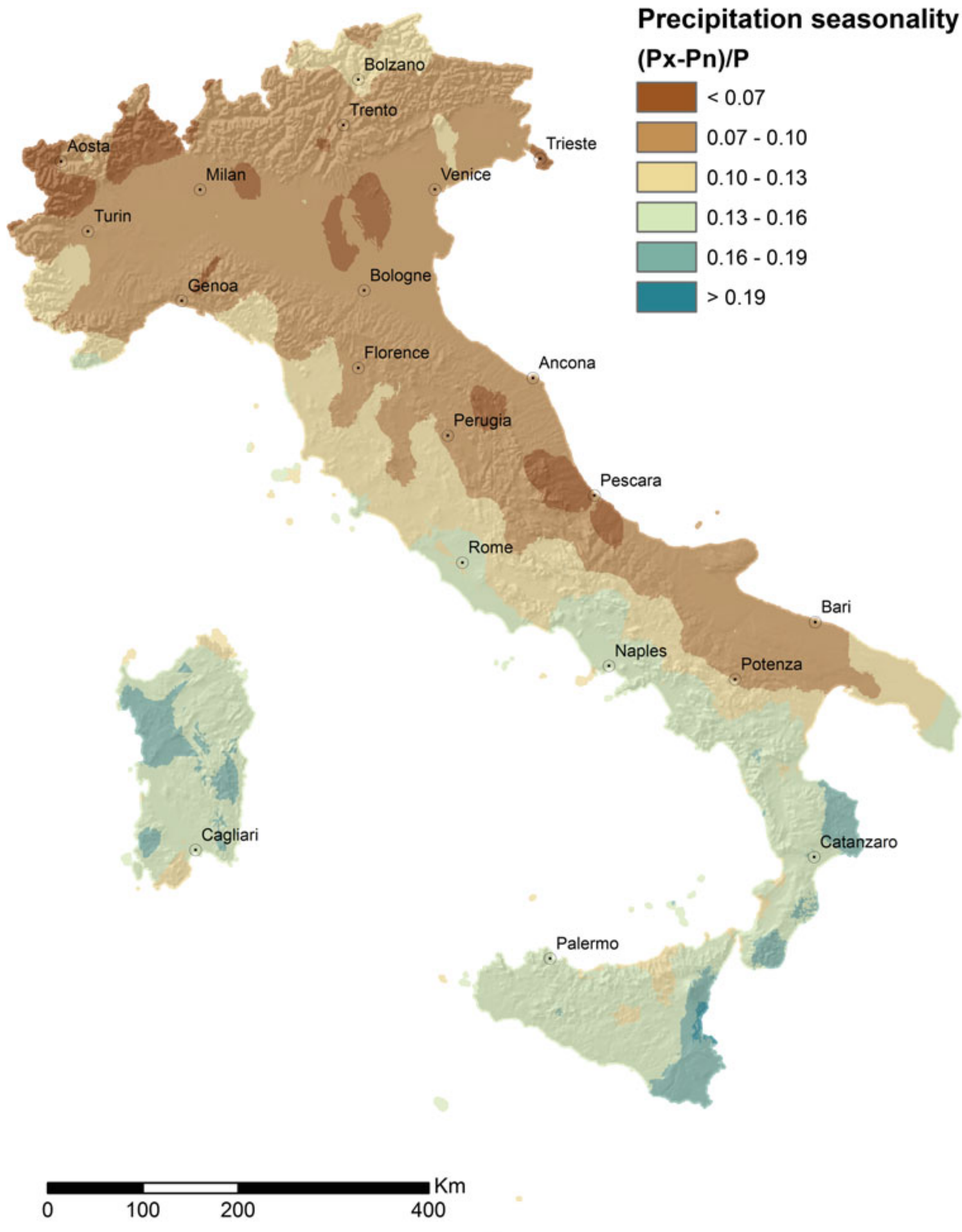


Fig. 2.7 Precipitation seasonality (1960–2008). Px is the precipitation of the rainiest month, Pn is the precipitation of the driest month, P is the annual precipitation

2.5 Climatic Regions of Italy

Following, as a reference, the climatic classification suggested in the georeferenced soil database for Europe[11] (Finke et al. 1998) and its most recent updating (Hartwich et al. 2006) in Italy there are 14 of the 35 climatic regions occurring in Europe. In particular, there are 4 of the 14 temperate climates and 10 out of the 11 Mediterranean climates[12] (Table 2.2, Fig. 2.10). Temperate climates dominate the Alps and the Northern Apennines; they are as follows:

T1-temperate continental climate influenced by mountains,
T2-temperate subcontinental influenced by mountains,
T3-temperate to warm temperate subcontinental, partly arid,
T4-temperate mountainous.

The T1 climate overlooks the highest mountains, and it is the coldest and least evapotranspirative environment (Table 2.2). Here, the snow cover distribution is a key

[11] The map of the "Soil Regions of the European Union and Adjacent Countries 1:5,000,000 (Version 2.0)" is published by the Federal Institute of Geosciences and Natural Resources (BGR), in partnership with the Joint Research Center (JRC, Ispra).

[12] The Mediterranean to warm temperate oceanic climate is present in Portugal but not in Italy.

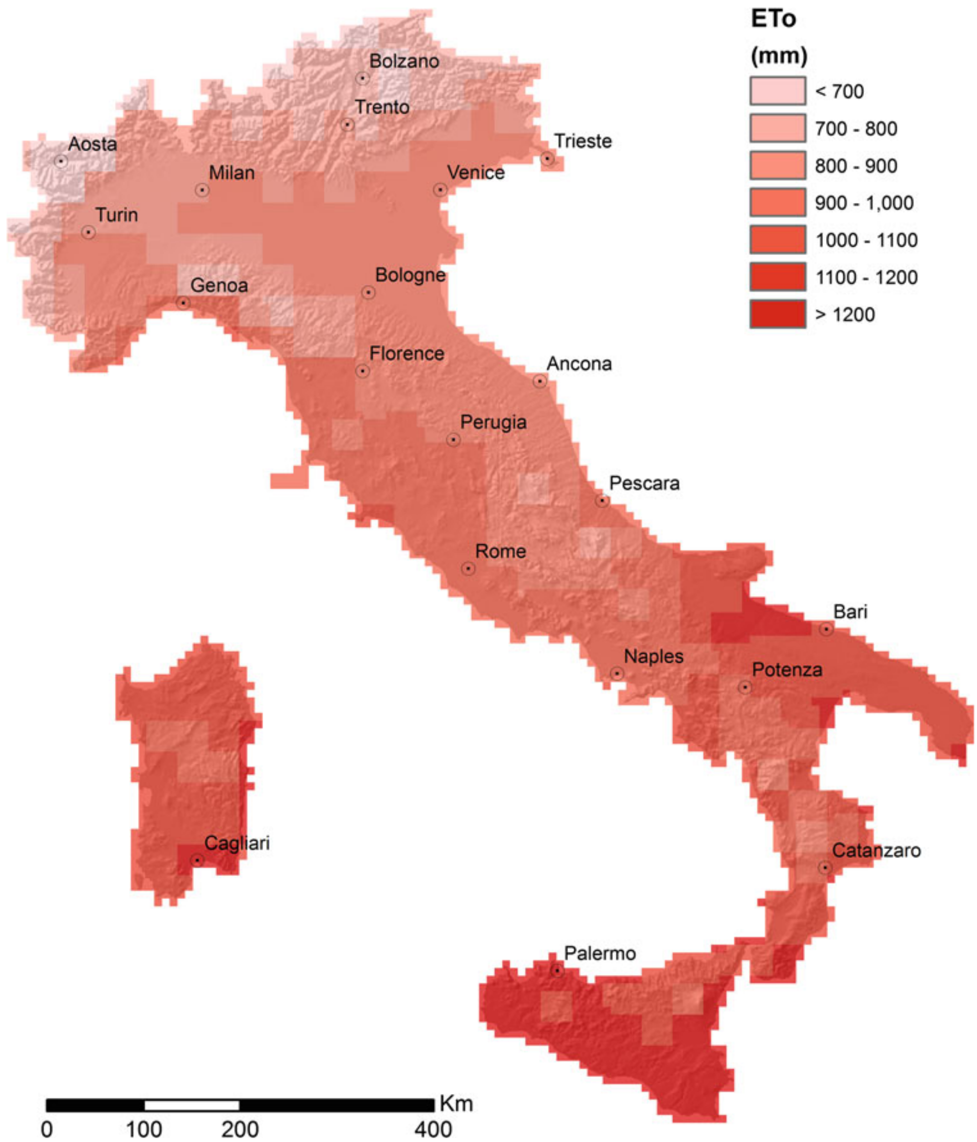


Fig. 2.8 Potential evapotranspiration (1961–1990)

factor, influencing, for example, the soil temperature (e.g., permafrost occurrence) and the soil water and nutrient availability. Most of Italian Cryosols can be found in this region. The T2 and T3 climates dominate lower elevations and have similar values of average temperature, degree of continentality and evapotranspirative demand, but are significantly different in terms of rainfall. Actually, soils located within the T3 climatic region receive average precipitations more than a third less than T2 (942 versus 1,356.2 mm) as a consequence of the more protected physiographic position. The different amount of water that can potentially percolate through the soil profile gives reason to the different distribution of typologies in these two climatic regions, in particular Podzols and Umbrisols.

The temperate mountainous climate (T4) is significantly warmer and moister than the others, in dependence of the exposition to the Atlantic as well as to the northern and eastern perturbations. This kind of climate can induce a large organic matter accumulation in soil, with the formation of Umbrisols and Phaeozems.

The intermediate Mediterranean to warm temperate climates, suboceanic (TM1) or mountainous (TM4) are actually widespread in the mountainous lands of both the Alps and the Apennines. They are much warmer than the previous ones, which motivates their intermediate Mediterranean classification, with different amounts of rainfall, significantly higher in the suboceanic climate. Cambisols are the dominant kind of soils, but at the highest elevations of TM1, Podzols are widespread. The other two intermediate climates, that is, Mediterranean suboceanic to subcontinental (TM2 and TM3) typify Po Plain and adjacent low hills. They are relatively warmer than the other climates of northern Italy, with a characteristic degree of continentality, that is, a rather high temperature difference between

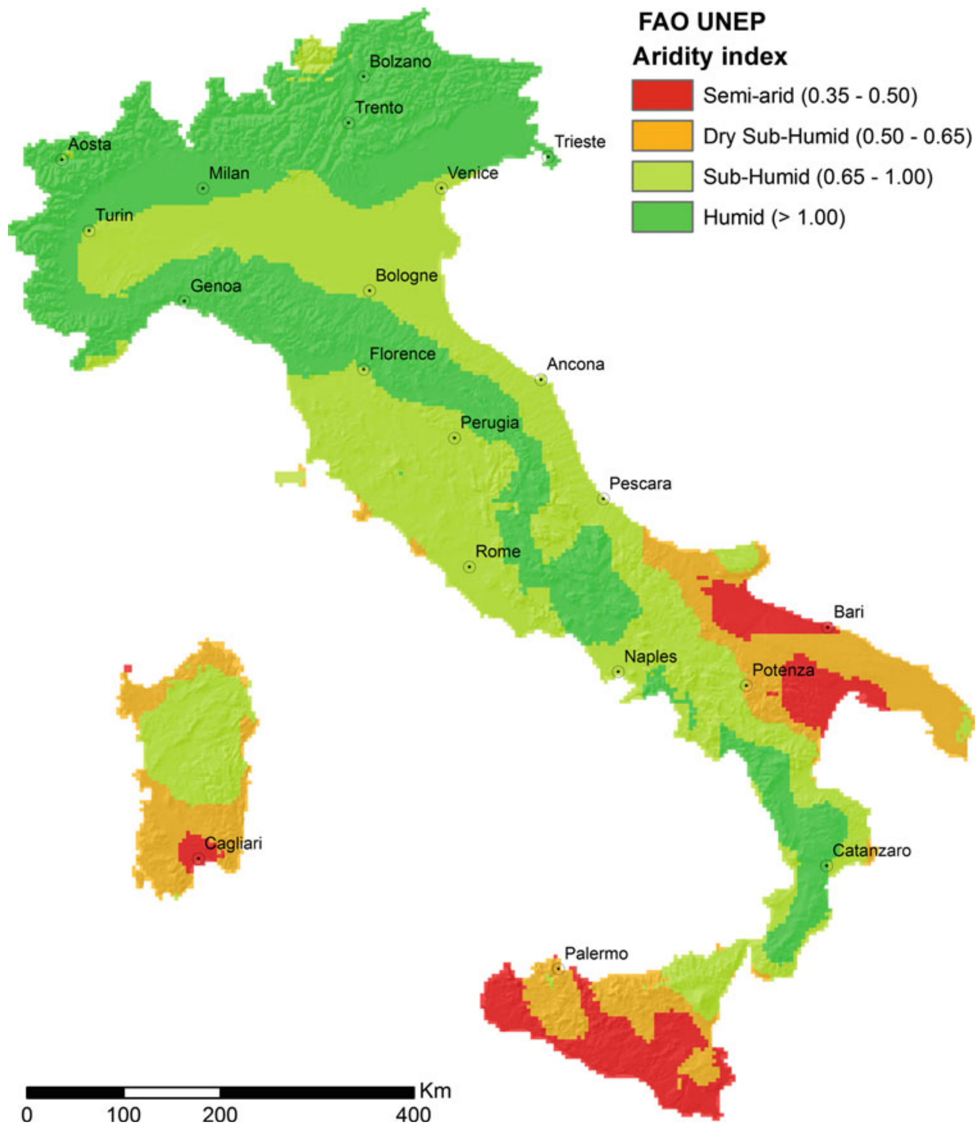


Fig. 2.9 Aridity index (precipitation/potential evapotranspiration, 1960–2008)

summer and winter and a quite regular precipitation pattern. Continentality influences markedly the vegetation, limiting the presence of olive tree and other Mediterranean species like cypresses (Cupressus sempervirens), bay laurel (Laurus nobilis) and Holm oak (Quercus ilex) and favors the accumulation of calcium carbonate in the subsurface horizons of soils formed on calcareous sediments. The relatively warm temperature and the rainfall pattern enhance weathering of the soil parent materials; therefore, on stable morphological positions, neogenetic clay can accumulate in depth and Luvisols dominate the soilscape.

Among the Mediterranean types of climate, two of them, namely M1 and M2, have suboceanic traits, that is, they are relatively more humid and have less evapotranspirative demand than the other Mediterranean ones. They are widespread all along the hills of the peninsula. More precisely, they are more frequent in central Italy, while they progressively shrink within the lands far from the sea in southern Italy and in the heart of the main islands, giving progressive way to the more characterized Mediterranean climates. The two climates are different in terms of degree of continentality, having M1 a significantly larger seasonal difference between mean temperatures, which induces the formation of Calcisols and Luvisols, when the other factors of soil formation are favorable. The M2 type of climate, instead, is more appropriate for the formation and preservation of Andosols on the widespread volcanic sediments.

A large part of the soils in the Southern Apennines have a so-called Mediterranean mountainous climate (M3), where Mediterranean traits of climate, like warm but seasonally contrasted temperatures, little continentality and large variability in winter precipitations, are counteracted by the relatively high amount of total rainfall and evapotranspirative demand, which vary markedly according to

Table 2.2 Descriptive statistics of the climatic regions of Italy

Variable	Temperature (°C)		Continentality index (°C)		Precipitation (mm)		Potential evapotranspiration (mm)	
Climatic region	mean	std	mean	std	mean	std	mean	std
T1 Temperate continental, influenced by mountains	1.6	2.5	15.6	0.2	925.5	145.6	716.3	38.8
T2 Temperate subcontinental, influenced by mountains	5.7	2.6	15.7	0.3	1356.2	149.8	774.1	61.2
T3 Temperate to warm temperate subcontinental, partly arid	6.9	2.4	15.7	0.4	942.0	111.8	772.8	62.7
T4 Temperate mountainous	9.0	2.6	15.6	0.3	1856.1	163.9	846.6	48.1
TM1 Mediterranean to warm temperate, suboceanic	11.3	1.7	15.6	0.4	1387.9	139.1	882.6	62.4
TM2 Mediterranean suboceanic to subcontinental, influenced by mountains	12.4	1.2	16.0	0.2	1066.1	105.3	899.6	37.0
TM3 Mediterranean suboceanic to subcontinental	13.5	0.5	16.4	0.3	800.5	74.1	921.3	23.9
TM4 Mediterranean to warm temperate mountainous	11.4	2.0	15.1	0.3	983.1	106.2	954.7	46.4
M1 Mediterranean suboceanic	13.5	1.4	15.2	0.2	840.9	90.5	1012.0	47.2
M2 Mediterranean suboceanic, influenced by mountains	13.9	1.6	14.5	0.2	870.8	91.0	1069.0	38.3
M3 Mediterranean mountainous	13.6	2.2	14.3	0.3	1205.7	130.5	1072.4	63.3
M4 Mediterranean subcontinental to continental, partly semiarid to arid	15.0	1.2	15.1	0.3	603.9	66.6	1155.4	43.4
MST1 Mediterranean to subtropical, influenced by mountains	15.5	1.2	13.9	0.3	811.3	110.4	1140.6	40.7
MST2 Mediterranean to subtropical, partly semiarid	16.7	1.0	14.2	0.3	606.6	66.8	1210.6	41.7

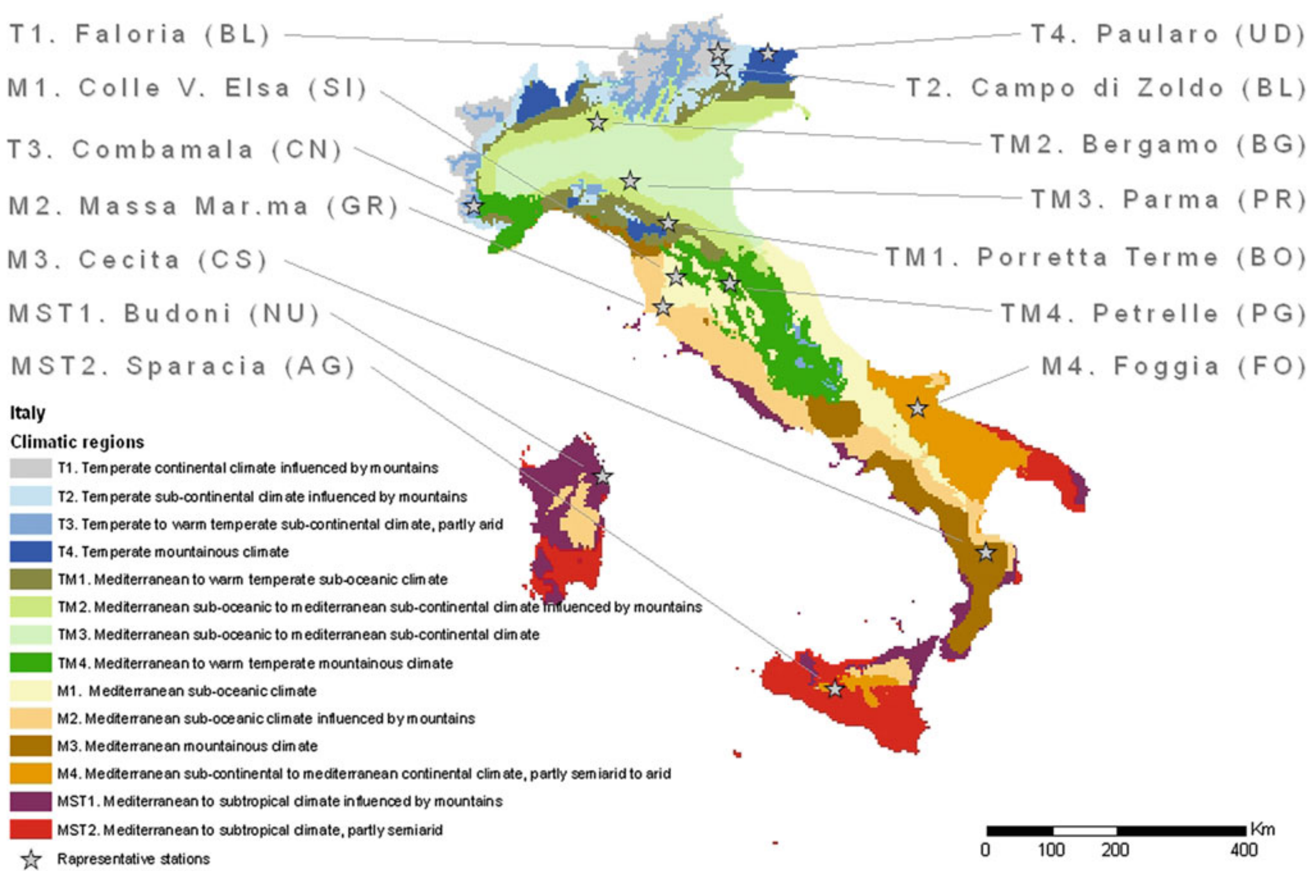


Fig. 2.10 Climatic regions of Italy and representative meteorological stations

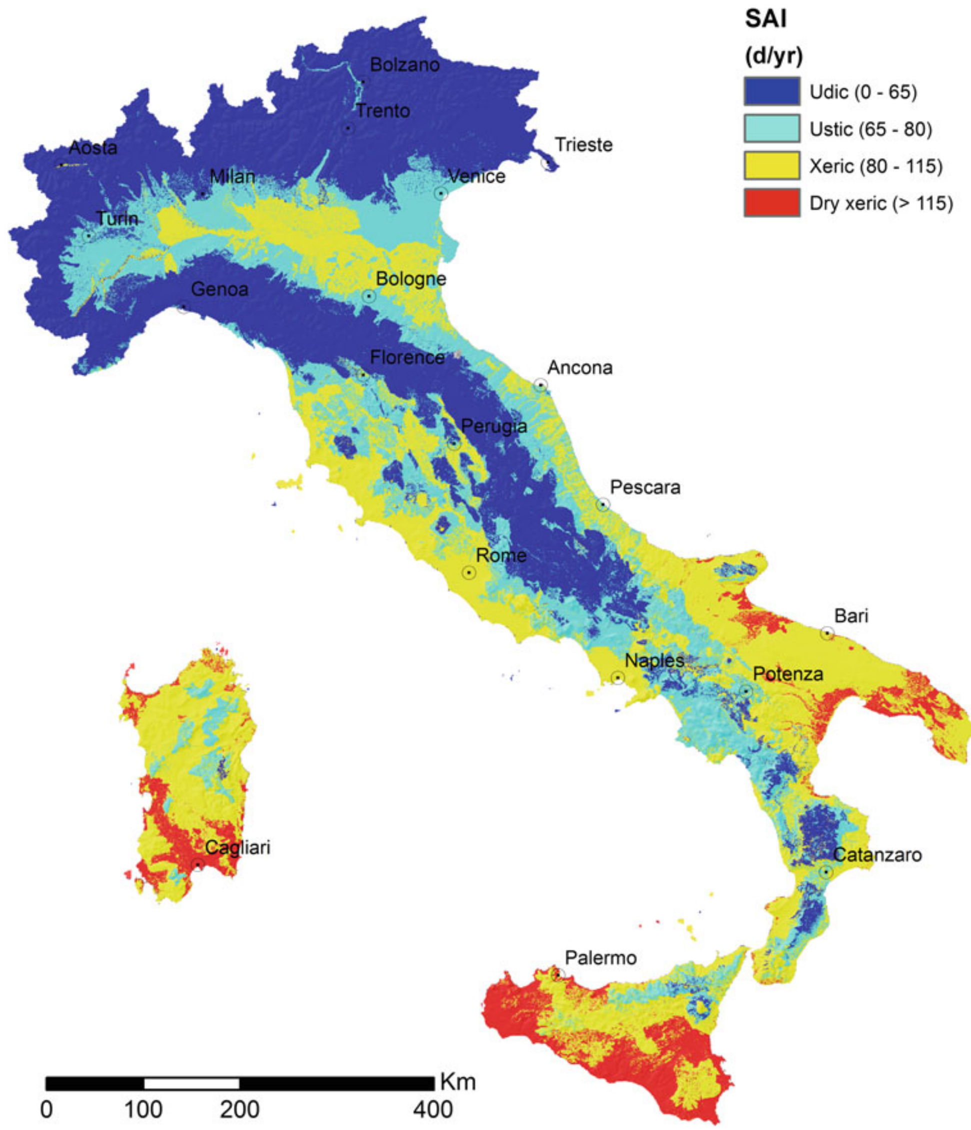


Fig. 2.11 Soil moisture regime and soil aridity index (Costantini et al. 2001)

elevation. On the highland, in particular, climatic conditions allow the formation and persistence of andic as well as umbric soil properties.

The Mediterranean subcontinental to Mediterranean continental climate, partly semiarid to arid (M4), characterizes large parts of the low hills and plains of the Apulia and Basilicata regions and some internal hills of Sicily. This climatic region, along with the two having intermediate Mediterranean to subtropical characteristics, are those where the most prominent traits of mediterraneity are emphasized by natural and cultivated vegetation. In addition to the plants of the Mediterranean macchia, the dwarf palm and prickly pear are endemic on well-drained soils. Among cultivated plants, the characteristic citrus fruit cultivation is present in irrigated lands. Evapotranspiration here is high, as well as continentality, while precipitation is low, so that most lands are affected by aridity. Salt accumulation in soils, in particular calcium carbonate, can be favoured by the limited leaching, and Calcisols development is favoured. In addition, the pronounced seasonal contrast supports the widespread formation of either Vertisols, on fine sediments and lowlands, or Chromic and Rhodic Cambisols and Luvisols, on better drained rocks and morphological positions (Mediterranean "Terra rossa" soils).

The last two climatic regions belong to the Mediterranean to subtropical climates, either partly semiarid (MST2) or influenced by mountains (MST1). Both are characterized by rather elevated air temperatures, with low seasonal differences and a high evapotranspirative deficit, notably larger in the semiarid climate. Pedogenesis here is slow, and soil either on instable morphological positions, or deeply affected by man-driven erosion, are often shallow and

Fig. 2.12 Soil temperature regimes according to Soil Taxonomy

poorly developed, so that they frequently belong to the classes of Regosols and Leptosols. On the other hand, on stable and preserved surfaces, the accumulation of organic matter and the formation of Chernozems and Kastanozems are favoured (Mediterranean "steppe").

2.6 Pedoclimate

To estimate the soil moisture regime according to Soil Taxonomy (Soil Survey Staff 1999), we calculated the soil aridity index (SAI), that is, the average number of days per year when the soil moisture control section[13] is dry (Costantini et al. 2002, 2005; Costantini and L'Abate 2009). The SAI can be used for the classification of the soil moisture regime, as well as to single out areas with a diverse degree of desertification risk (Costantini et al. 2009).

The average number of dry days in Italy ranges conspicuously, from nil to almost 5 cumulative months, in the driest xeric conditions (Table 2.1). Figure 2.11 shows that the ustic soil moisture regime is the relatively most widespread udometric regime, being present both in the Mediterranean and in the intermediate Mediterranean to temperate climatic regions. While the udic regime dominates the Alps and the Apennines chains, xeric and dry xeric

[13] The soil moisture control section makes reference to the upper part of the soil, where roots of herbaceous species concentrate. SAI (days/year) = 44.532605 + [mean annual air temperature] × 7.310365 − [rainfall] × 0.061497 − [cumulative available water up to 50 cm, in mm] × 0.229448.

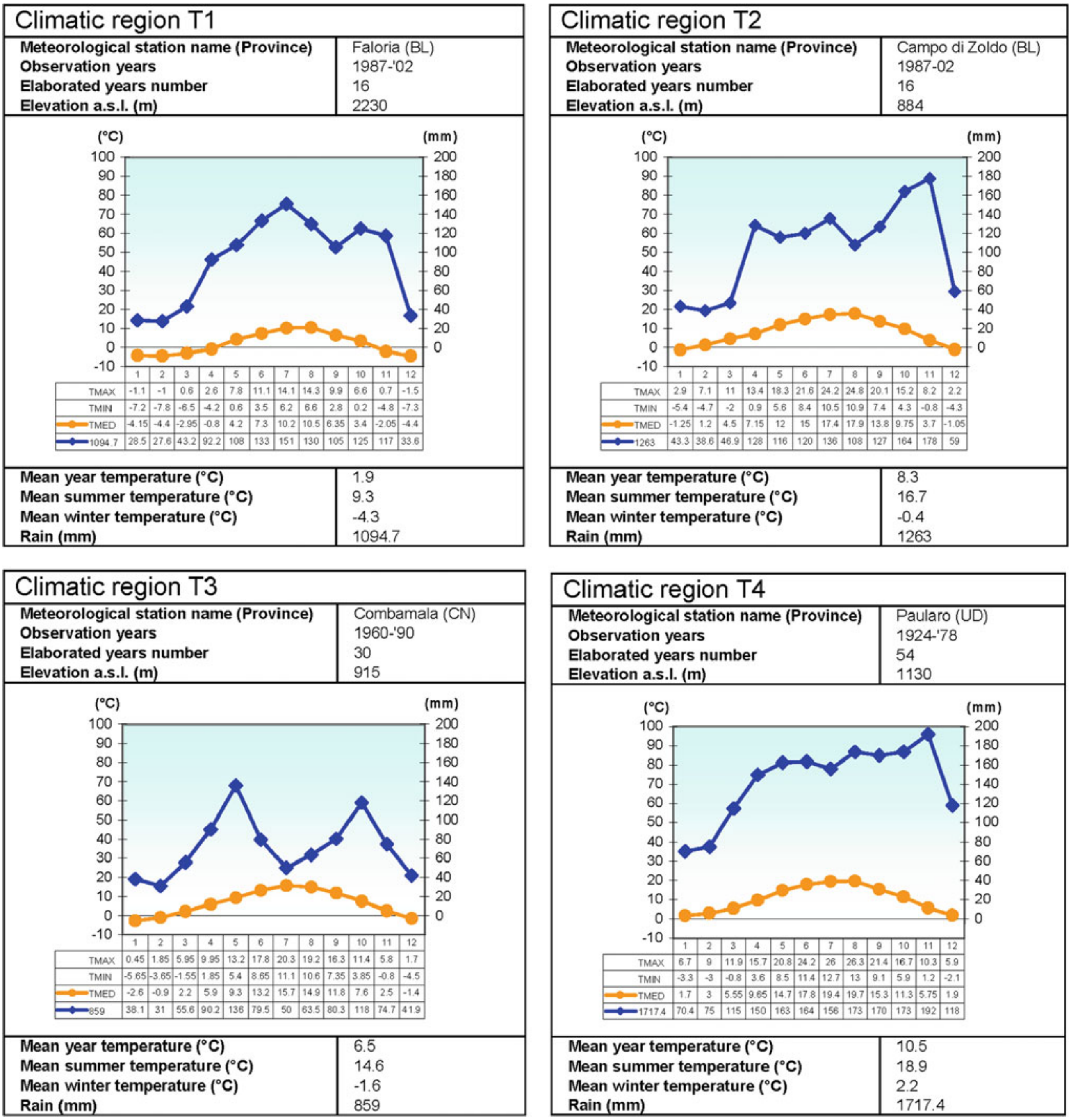


Fig. 2.13 Representative meteorological stations for the temperate climates of Italy

are well correlated with lands with the highest aridity. It is interesting to note that soils with xeric moisture regime are also present in the Po Plain and in central Italy.

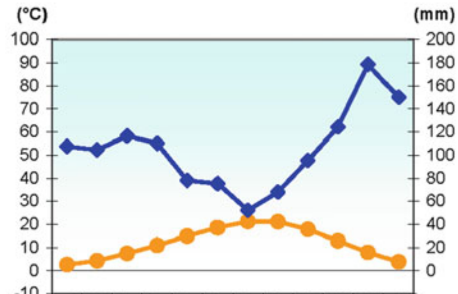
As for soil temperature regime classification (Soil Survey Staff 1999), that is, average soil temperature at 50 cm (MST),[14] the mesic soil temperature regime dominates most part of the country (Table 2.1). The thermic regime dominates southern Italy, but is also frequent in the central part of the country and even in northern Italy. The map reported in Fig. 2.12[15] highlights the occurrence of the frigid and cryic

[14] Soil temperature was calculated in function of the mean annual air temperature and soil water content at field capacity (see note 15).

[15] The map was obtained from raster datasets of field capacity (FC) at 50 cm depth (not shown in this atlas) and long-term mean annual air temperatures. The first raster was obtained by geographical join of FC values of 18,449 soil sites to land components (features belonging to

Climatic region TM1

Meteorological station name (Province)	Porretta Terme (BO)
Observation years	1956-'84
Elaborated years number	28
Elevation a.s.l. (m)	349

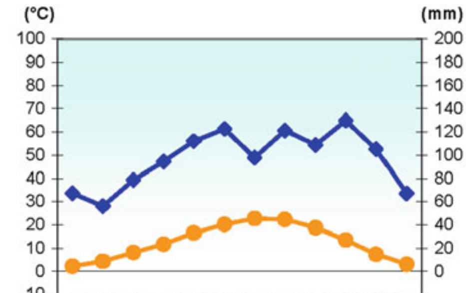


	1	2	3	4	5	6	7	8	9	10	11	12
TMAX	7.4	9.5	13.1	17	21.7	25.6	28.9	28.7	24.6	18.8	12.8	8.4
TMIN	-2.1	-0.8	1.9	4.9	8.2	11.6	13.6	13.6	11.1	7	3.1	-0.7
TMED	2.65	4.35	7.5	11	15	18.6	21.3	21.2	17.9	12.9	7.95	3.85
1261.2	108	105	117	110	78.1	75.4	52.1	68	95.5	124	179	150

Mean year temperature (°C)	12.0
Mean summer temperature (°C)	20.3
Mean winter temperature (°C)	3.6
Rain (mm)	1261.2

Climatic region TM2

Meteorological station name (Province)	Bergamo (BG)
Observation years	1958-'01
Elaborated years number	44
Elevation a.s.l. (m)	266

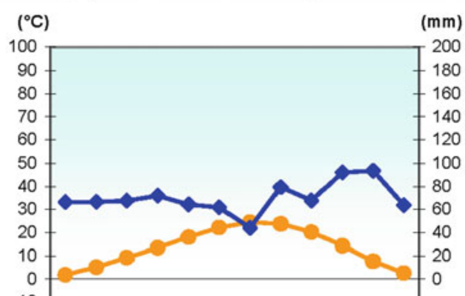


	1	2	3	4	5	6	7	8	9	10	11	12
TMAX	6	8.6	12.9	16.7	21.8	25.7	28.3	27.7	23.8	17.9	11	6.7
TMIN	-1.5	0.2	3.5	6.8	11.4	14.8	17.3	17.1	13.8	9.3	3.8	-0.5
TMED	2.25	4.4	8.2	11.8	16.6	20.3	22.8	22.4	18.8	13.6	7.4	3.1
1161.8	67.3	56.2	78.8	94.5	112	123	97.9	121	109	130	105	67

Mean year temperature (°C)	12.6
Mean summer temperature (°C)	21.8
Mean winter temperature (°C)	3.3
Rain (mm)	1161.8

Climatic region TM3

Meteorological station name (Province)	Parma (PR)
Observation years	1961-'80
Elaborated years number	20
Elevation a.s.l. (m)	56

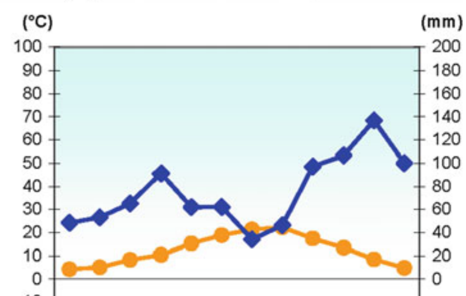


	1	2	3	4	5	6	7	8	9	10	11	12
TMAX	4.6	8.8	14	18.8	23.9	28.3	30.6	29.6	25.5	18.7	10.6	5.3
TMIN	-1	1.5	4.6	8.2	12.3	16.1	18.4	17.9	14.9	10	4.8	-0.1
TMED	1.8	5.15	9.3	13.5	18.1	22.2	24.5	23.8	20.2	14.4	7.7	2.6
839.4	66.5	66.5	67.6	72	64.3	61.8	44.1	79.4	67.8	92.2	93.5	63.7

Mean year temperature (°C)	13.6
Mean summer temperature (°C)	23.5
Mean winter temperature (°C)	3.2
Rain (mm)	839.4

Climatic region TM4

Meteorological station name (Province)	Petrelle (PG)
Observation years	1991-'02
Elaborated years number	12
Elevation a.s.l. (m)	362



	1	2	3	4	5	6	7	8	9	10	11	12
TMAX	8.7	10.8	14.5	16.4	22.1	26.2	29.2	30.4	24.2	19.1	12.9	8.8
TMIN	-0.1	-0.5	2.2	4.4	8.6	11.5	13.5	14.1	10.7	8	4.2	0.9
TMED	4.3	5.15	8.35	10.4	15.4	18.9	21.4	22.3	17.5	13.6	8.55	4.85
903.1	48.4	53.2	65.2	91.2	62	62.2	34.1	46.3	97.2	107	137	99.9

Mean year temperature (°C)	12.5
Mean summer temperature (°C)	20.8
Mean winter temperature (°C)	4.8
Rain (mm)	903.1

Fig. 2.14 Representative meteorological stations for the intermediate Mediterranean to temperate climates of Italy

regimes in a large area of the Alps. In the Apennines, however, it could be underestimated, because of the scarcity of both meteorological and pedological data.

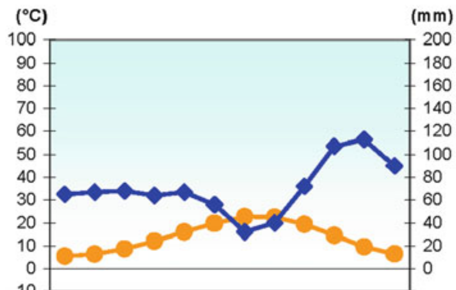
(Footnote 15 continued)
different soil region and with different lithology, land use and physiography) obtained from a 500 m grid and other databases. MST = [mean annual air temperature] + (([FC] × 100) − 20.7)/7.9. Frigid–cryic regime makes reference to both annual and summer mean air temperatures.

2.7 Characteristics Ombrothermic Diagrams

The long-term temperature and precipitation trends of some meteorological stations, selected as a reference of the different climatic regions of Italy, are illustrated in the following figures (Figs. 2.13, 2.14, 2.15, 2.16) (see Fig. 2.10 for their placement).

Climatic region M1

Meteorological station name (Province)	Colle V. Elsa (SI)
Observation years	1951-'89
Elaborated years number	39
Elevation a.s.l. (m)	235

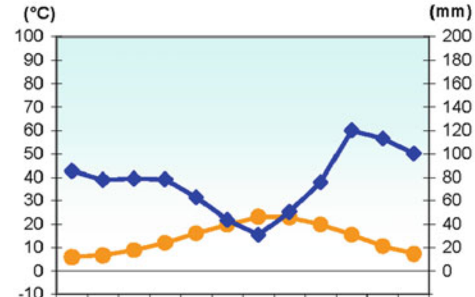


	1	2	3	4	5	6	7	8	9	10	11	12
TMAX	10.5	11.8	14.5	18.4	22.8	26.9	30.4	30.2	26.4	20.7	14.9	11.2
TMIN	0.6	1.1	3	5.7	9.2	12.7	14.9	14.8	12.4	8.3	4.4	1.8
TMED	5.55	6.45	8.75	12.1	16	19.8	22.7	22.5	19.4	14.5	9.65	6.5
841	65	67	68	64	67	56	32	40	72	107	113	90

Mean year temperature (°C)	13.7
Mean summer temperature (°C)	21.7
Mean winter temperature (°C)	6.2
Rain (mm)	841

Climatic region M2

Meteorological station name (Province)	Massa Mar.ma (GR)
Observation years	1951-93
Elaborated years number	42
Elevation a.s.l. (m)	370

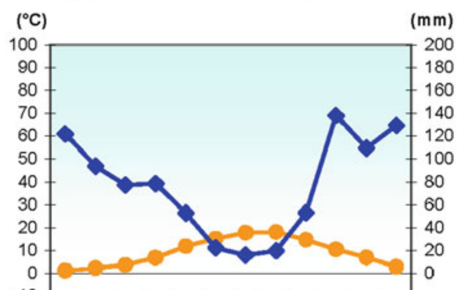


	1	2	3	4	5	6	7	8	9	10	11	12
TMAX	9.8	10.8	13.5	17	21.6	25.6	29.2	28.9	25.5	20.2	14.6	11.1
TMIN	2	2.5	4.2	7	10.7	14	17.1	17	14.4	10.8	6.5	3.5
TMED	5.9	6.65	8.85	12	16.2	19.8	23.2	23	20	15.5	10.6	7.3
918.4	85.4	78	79	78.3	62.9	43.7	31	50.4	76	120	113	100

Mean year temperature (°C)	14.1
Mean summer temperature (°C)	22.0
Mean winter temperature (°C)	6.6
Rain (mm)	918.4

Climatic region M3

Meteorological station name (Province)	Cecita (CS)
Observation years	1955-'70
Elaborated years number	15
Elevation a.s.l. (m)	1180

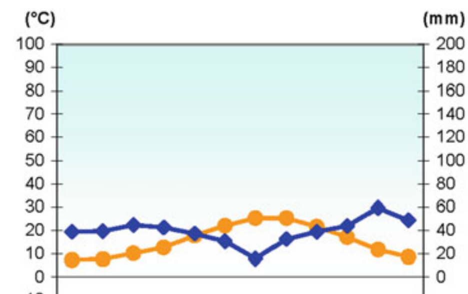


	1	2	3	4	5	6	7	8	9	10	11	12
TMAX	4.6	6.5	7.8	11.6	17.6	21.4	24.9	25.3	20.8	15.6	11	6
TMIN	-2	-1.7	-0.3	2.2	6.2	9.1	10.8	11.1	8.7	5.4	2.9	0
TMED	1.3	2.4	3.75	6.9	11.9	15.3	17.9	18.2	14.8	10.5	6.95	3
912.4	122	93.9	77.4	78.6	52.7	22.2	16	19.8	53	138	110	130

Mean year temperature (°C)	9.4
Mean summer temperature (°C)	17.1
Mean winter temperature (°C)	2.2
Rain (mm)	912.4

Climatic region M4

Meteorological station name (Province)	Foggia (FG)
Observation years	1977-1997
Elaborated years number	21
Elevation a.s.l. (m)	70



	1	2	3	4	5	6	7	8	9	10	11	12
TMAX	11.4	12.3	15.5	18.5	24.2	28.9	32.2	31.9	27.6	22.3	16	12.6
TMIN	3.2	3	4.7	6.8	11.4	15.3	18.5	18.8	15.7	11.9	7.4	4.6
TMED	7.3	7.65	10.1	12.7	17.8	22.1	25.4	25.4	21.7	17.1	11.7	8.6
472.5	39	39.4	44.8	42.6	37.2	30.6	15.7	32.4	38.9	43.9	59.3	48.7

Mean year temperature (°C)	15.6
Mean summer temperature (°C)	24.3
Mean winter temperature (°C)	7.9
Rain (mm)	472.5

Fig. 2.15 Representative meteorological stations for the Mediterranean climates of Italy

2.8 Climate Change and Soil

The World Meteorological Organisation has defined as the "norm" of a climatic variable the calculated average value for a uniform period of three consecutive decades (World Meteorological Organization, 1984, 1989). The climatic thirty years 1961–1990 have been used as a reference for many climatology studies (Beltrano et al. 2007). According to Vento (2004), a general climatic change occurred in Italy in the period 1961–2000, with a general reduction in mean annual precipitation and the number of rainy days, and a

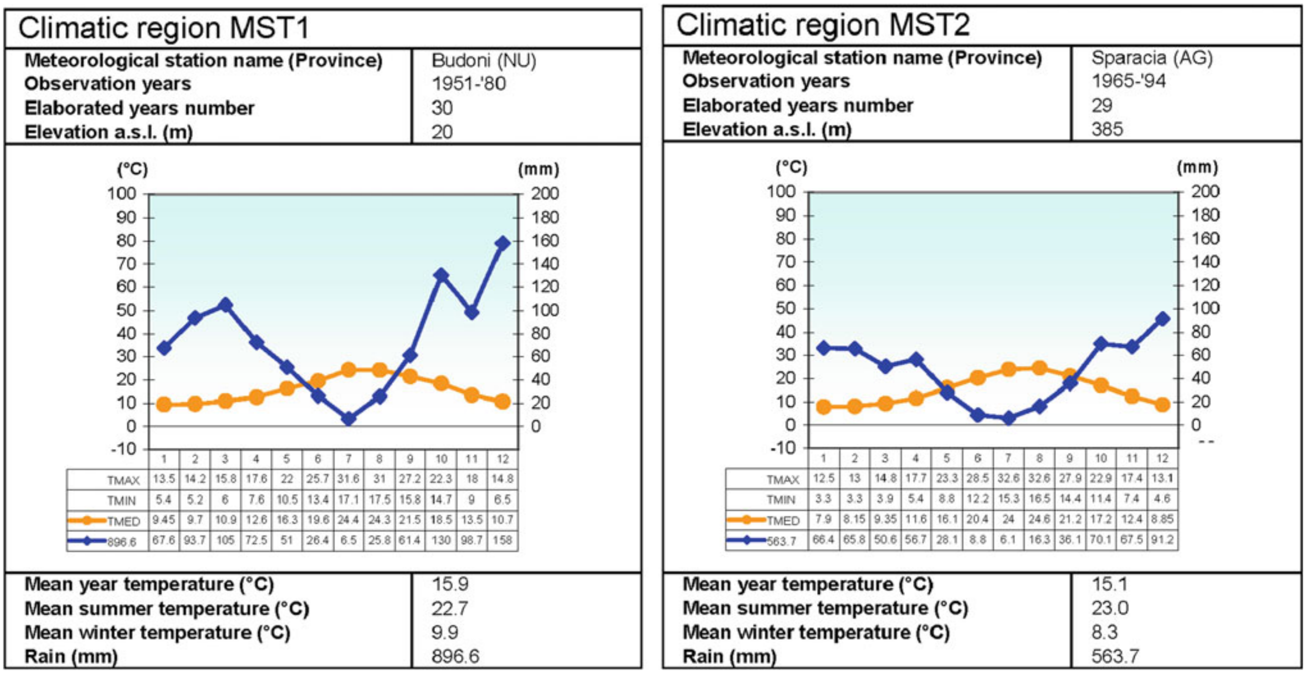


Fig. 2.16 Representative meteorological stations for the intermediate Mediterranean to subtropical climates of Italy

Table 2.3 Mean annual air temperature and annual precipitation in Italy before and after the year 1990 (significance of the difference between the means checked with the Student's statistical t-test at the $P < 0.01$ level)

	1978–1990	1991–2006
	Mean	Mean
MAT °C	13.02 B	13.72 A
MAP mm/year	811.56 A	722.66 B

Elaboration conducted on the national meteorological grid (Perini et al. 2004)

general increase in mean air temperatures. Regional studies confirmed this trend with some local exceptions (Cacciamani et al. 2001; Buffoni et al. 2003; Brunetti et al. 2004; Maugeri et al. 2004; Genesio et al. 2006; Barbi et al. 2007).

Fantappiè and collaborators (Fantappiè et al. 2010, 2011), who investigating the soil organic carbon stock variations in Italy during the last three decades, also found a significant increase in mean air temperature (MAT), which was 13.02 °C in the time frame 1978–1990 but reached 13.72 °C between 1991 and 2006 (Table 2.3[16]). Mean annual precipitations (MAP) significantly decreased from 811.56 to 722.66 mm/year. Figures 2.17 and 2.18 describe

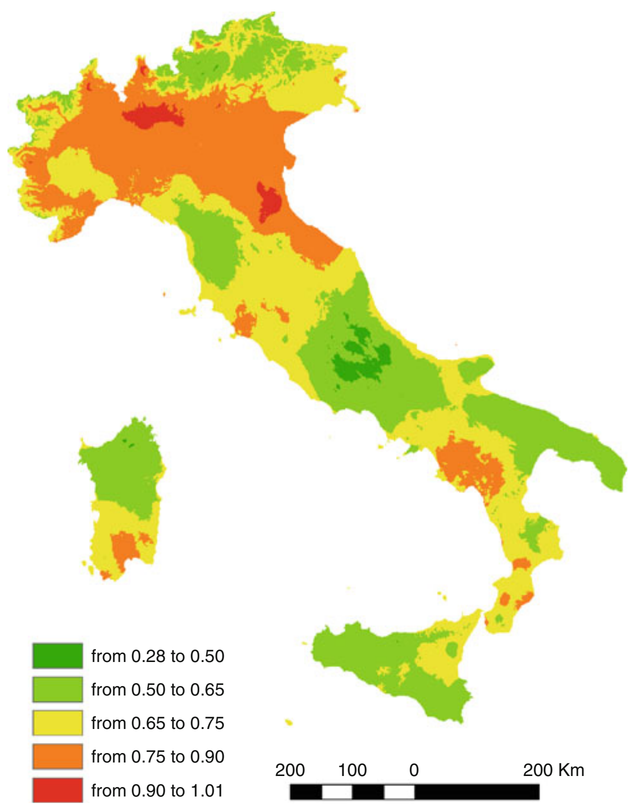


Fig. 2.17 Mean annual air temperatures variations (°C) in Italy from 1978 to 1990 and from 1991 to 2006 years. Differences between legend classes are larger than standard errors

[16] Elaboration conducted on the national meteorological grid (Perini et al. 2004).

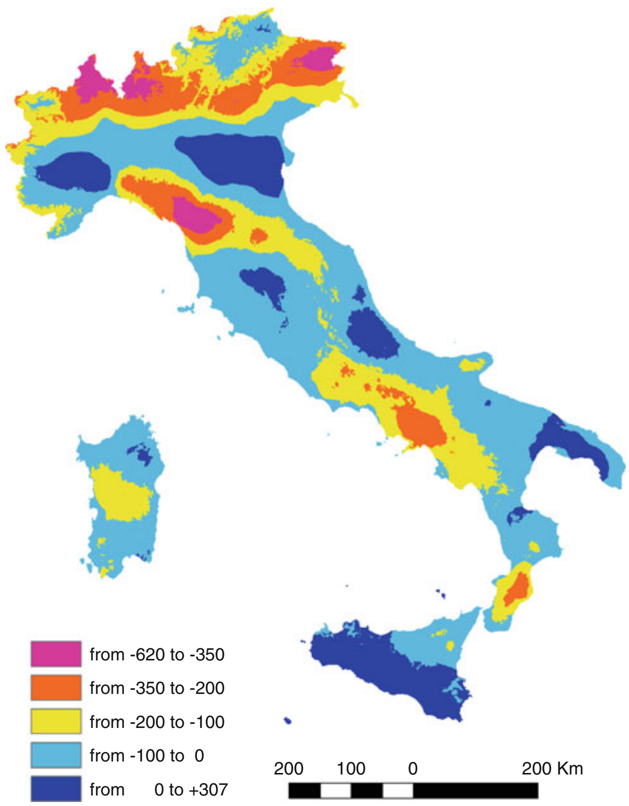


Fig. 2.18 Mean annual precipitations variations (mm y^{-1}) in Italy from 1978 to 1990 and from 1991 to 2006 years. Differences between legend classes are larger than standard errors

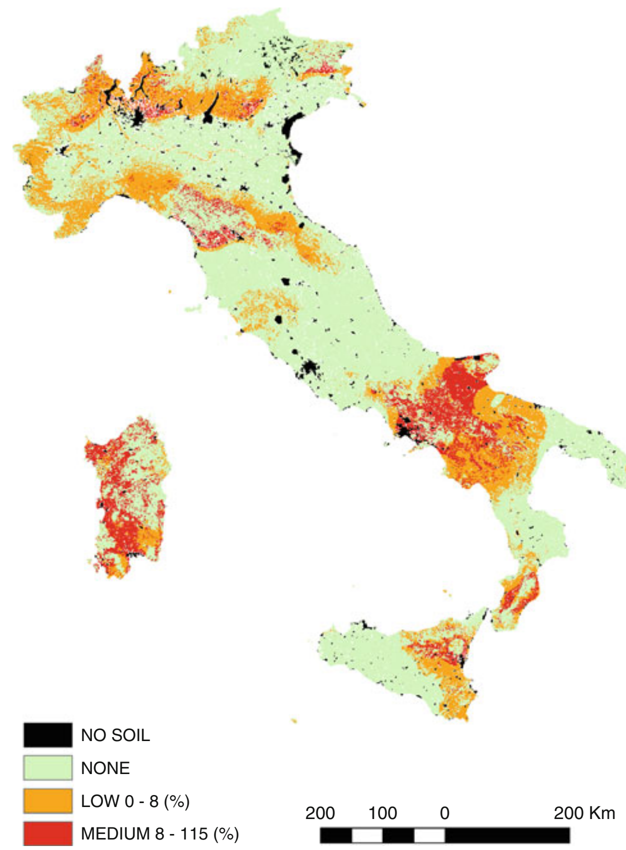


Fig. 2.19 Index of climate change influence (%) on SOC content variations between the years 1978–1990 and 1991–2006. Differences between legend classes are larger than standard errors

the spatial pattern of variations. Figure 2.17 highlights that temperature increased especially at lower altitudes and higher latitudes. In particular, the Po Plain showed the highest MAT increases, whereas some parts of central Italy (Abruzzo and Lazio regions) the lowest. MAP generally decreased between the two reference periods all over the country, with the exception of southern Sicily and of some limited areas of southern and northern Italy (Fig. 2.18). The most prominent decreases were localized in different parts of the country (the Alps, the Apuan Alps, the Tosco-Emilian Apennines, Campania and Calabria regions).

Organic carbon content (SOC) is a soil property that can be affected by climate change (Siegenthaler et al. 2006). The mentioned authors (Fantappiè et al. 2011) found that the observed climate change which occurred between the two periods had a general low influence on SOC variations (Fig. 2.19). Nevertheless, the relatively higher climatic influence occurred in meadows and in arable lands with a moderate or high MAP decrease (<−100 mm/y) and a moderate to high MAT increase (>0.62 °C). The decreasing SOC content of lands with increasing hot and arid climate could be a soil indicator of the consequences of the extension of the Mediterranean subtropical climatic regions in Italy.

A reduction in snow cover associated with global warming may be another important effect of climate change on areas at higher elevation, in particular in the montane belt. As warming progresses in the future, regions where snowfall is the current norm will increasingly experience precipitation in the form of rain. Deep persistent snow cover may keep the soil free of frost throughout the winter, while shallow, ephemeral snow packs tend to promote soil freezing, with important consequences on soil nutrient dynamics (e.g., increase in N losses) (Edwards et al. 2007; Freppaz et al. 2007, 2008; Filippa et al. 2009).

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References

Allen RG, Pereira LS, Raes D, Smith M (1998) Crop evapotranspiration: guidelines for computing crop water requirements. United nations food and agriculture organization, irrigation and drainage paper 56. Italy, p 300

Arnoldus HMJ (1977) Methodology used to determine the maximum potential average annual soil loss due to sheet and rill erosion in Morocco, vol 34. Annex IV, FAO soils bull. Roma, pp 39–48

Barbi A, Chiaudani A, Delillo I, Borin M, Berti A (2007) Andamenti agroclimatici nella regione veneto nel periodo 1956-2004. In: AIAM 2007—10° Convegno nazionale di Agrometeorologia: Quaderno degli Abstract. Italian Journal of Agrometeorology (1) supplemento, pp 14–15

Beltrano MC, Di Giuseppe E, Esposito S, Vento D (2007) Anomalie mensili di temperatura e precipitazione calcolate su differenti basi climatiche. In: AIAM 2007—10° Convegno nazionale di Agrometeorologia: Quaderno degli Abstract. Italian Journal of Agrometeorology (1) supplemento, pp 11–13

Brunetti M, Maugeri M, Monti F, Nanni T (2004) Changes in daily precipitation frequency and distribution in Italy over the last 120 years. J Geophys Res 109:D05102. doi:10.1029/2003JD004296

Buffoni L, Brunetti M, Mangianti F, Maugeri M, Monti F, Nanni T (2003) Ricostruzione del clima italiano negli ultimi 130 anni e scenari per il XXI secolo. In: Atti workshop "CLIMAGRI—Cambiamenti Climatici e Agricoltura", Cagliari, pp 16–17

Cacciamani C, Deserti M, Marletto V, Tibaldi S, Violetti D, Zinoni F (2001) Mutamenti climatici, situazione e prospettive. In: Quaderno tecnico ARPA-SMR 03, febbraio 2001. ARPA Emilia-Romagna, Servizio meteorologico regionale. (on line) http://www.arpa.emr.it/cms3/documenti/_cerca_doc/calore/Quaderno_Tecnico_03_2001.pdf

Costantini EAC, L'Abate G (2009) A soil aridity index to asses desertification risk for Italy. In: Faz Cano A, Mermut AR, Arocena JM, Ortiz Silla R (eds) Land degradation and rehabilitation—dryland ecosystems-Advances in GeoEcology 40. Catena Verlag, Germany, pp 231–242

Costantini EAC, Castelli F, Iori M, Magini S, Lorenzoni P, Raimondi S (2001) Regime termico del suolo in alcuni campi sperimentali del nord, centro e sud Italia. Atti del convegno SISS "La scienza del suolo in Italia: bilancio di fine secolo." Gressoney Saint Jean, 1999, (CD-ROM computer file), ISNP, Roma

Costantini EAC, Castelli F, Lorenzoni P, Raimondi S (2002) Assessing soil moisture regimes with traditional and new methods. Soil Sci Soc Am J 66:1889–1896

Costantini EAC, Castelli F, L'Abate G (2005) Use of the EPIC model to estimate soil moisture and temperature regimes for desertification risk in Italy. Adv GeoEcology, pp 251–263

Costantini EAC, Urbano F, Aramini G, Barbetti R, Bellino F, Bocci M, Bonati G, Fais A, L'Abate G, Loj G, Magini S, Napoli R, Nino P, Paolanti M, Perciabosco M, Tascone F (2009) Rationale and methods for compiling an atlas of desertification in Italy. Land Degrad Develop. 20:261–276

Edwards AC, Scalenghe R, Freppaz M (2007) Changes in the seasonal snow cover of alpine regions and its effect on soil processes: a review. Quatern Int 162–163:172–181

Fantappiè M, L'Abate G, Costantini EAC (2010) Factors influencing soil organic carbon stock variations in italy during the last three decades. In: Zdruli P et al (eds) Land degradation and desertification: assessment, mitigation and remediation, Springer, Netherlands, pp 435–465. doi:10.1007/978-90-481-8657-0_34

Fantappiè M, L'Abate G, Costantini EAC (2011) The influence of climate change on the soil organic carbon content in Italy from 1979 to 2008. Geomorphology 135:343–352

Filippa G, Freppaz M, Zanini E (2009) Suolo e neve in ambiente alpino: effetti sul ciclo dell'azoto. Studi Trentini di Scienze Naturali, 85:121–129, ISSN: 2035-7699

Finke P, Hartwich R, Dudal R, Ibanez J, Jamagne M, King D, Montanarella L, Yassoglu N (1998) Georeferenced soil database for Europe. EUR 18092, Ispra, Italy

Freppaz M, Williams BL, Edwards AC, Scalenghe R, Zanini E (2007) Simulating soil freeze/thaw cycles typical of winter alpine conditions: implications for N and P availability. Appl Soil Ecol 35:247–255

Freppaz M, Marchelli M, Celi L, Zanini E (2008) Snow removal and its influence on temperature and N dynamics in alpine soils (Vallée d'Aoste—NW Italy). J Plant Nutr Soil Sci 171:672–680

Genesio L, Vaccari FP, Maracchi G, Magno R, Ferrari R, Crisci A, Bottai L (2006) I diagrammi del clima in toscana. In: Genesio L, Vaccari FP (ed). CNR—Ibimet (Istituto di Biometeorologia), Firenze (on line) www.case.ibimet.cnr.it/desertnet/download/01_I_Diagrammi_del_Clima_in_Toscana.pdf

Hartwich R, Thiele S, Baritz R, Fuchs M, Krug D (2006) Erläuterungen zur Bodenregionenkarte der Europäischen Union und ihrer Nachbarstaaten im Maßstab 1:5.000.000. (Version 2.0) [The report additionally contains the Map of Climate Areas in Europe 1:10,000,000, and the Parent Material Associations Map 1:5,000,000. These products were developed for Finke et al. (1998) which is currently under revision]. BGR, Hannover

Maugeri M, Brunetti M, Buffoni L, Mangianti F, Monti F, Nanni T (2004) Recupero, esame critico, omogeneizzazione ed analisi di serie storiche secolari italiane di dati meteorologici. In: Esposito S, e Epifani C (eds) Progetto di Ricerca CLIMAGRI—Cambiamenti climatici e agricoltura—Risultati attività II anno. Roma. (on line) http://www.climagri.it/pubblicazioni/n.23/Articolo_1_1.pdf

Perini L, Beltrano MC, Dal Monte G, Esposito S, Caruso T, Motisi A, Marra FP, Ceccarelli T (2004) Atlante agro climatico, agro climatologia, pedologia, fenologia del territorio italiano. Ufficio Centrale di Ecologia Agraria (UCEA), Roma, p 64

Siegenthaler U, Stocker TF, Monnin E, Lüthi D, Schwander J, Stauffer B, Raynaud D, Barnola JM, Fischer H, Masson-Delmotte V, Jouzel J (2006) Stable carbon cycle–climate relationship during the late pleistocene. Science 310:1313–1317

Soil Survey Staff (1999) Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys, 2nd edn. US Department of Agriculture Soil Conservation Service, Washington

UNEP (1992) World atlas of desertification. United Nations Environment Programme

Vento, D (2004) Il clima in Italia negli ultimi decenni. Rivista dell'Agenzia Regionale Prevenzione Ambiente dell'Emilia Romagna, p 36

WMO (1984) Technical regulations. Vol. I, Publication No. 49, Geneva, CH

WMO (1989) Calculation of Monthly and Annual 30-Year Standard Normals. WCDP-n.10, WMO-TD/N.341, Geneva, CH

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