# CAMBIO CLIMÁTICO REGIONAL Y SUS IMPACTOS

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# VI CONGRESO INTERNACIONAL DE LA ASOCIACIÓN ESPAÑOLA DE CLIMATOLOGÍA

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# CLIMATIC INDICES IN ASSESSING OF TEMPERATURE AND PRECIPITATION PATTERNS IN TURKEY

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**ABSTRACT**

Climatic indices are diagnostic tools used to describe climatic conditions and the state of a climate system. The objective of this study is to assess the temperature and pressure patterns using climatic indices. Turkey is located in the Mediterranean macroclimatic zone. The country lies between the temperate and sub-tropical zones with a 630 mm annual precipitation. The climate of Turkey varies greatly from region to region. e.g. Mediterranean, Semi humid Marmara, Black Sea, Steppe and Continental and Eastern Anatolia climates. Central Anatolia is under the influence of a steppe climate with arid conditions while Eastern Black Sea coastal areas in the northeast have a relatively wetter climate.

The climatic indices were calculated over Turkey by using monthly temperature and precipitation for the period 1960-2006 at 232 stations in Turkey. The climatic indices used in this study are De Martonne Aridity Index and Pinna Combinative Index. An aridity index is a numerical indicator of the degree of dryness of the climate at a given location. The basic of De Martonne formula gives an index of aridity ($I_{DM}$). The aridity index may be related to climatic regimes in a broad sense e.g. dry, semi-arid, Mediterranean, semi-humid, humid and very-humid regions are defined by the aridity index ranges of $I_{DM}<10$; $10\leq I_{DM}<20$; $20\leq I_{DM}<24$;$24\leq I_{DM}<28$;$28\leq I_{DM}<35$ and $I_{DM}\geq 35$. The index values varied from 11.8 (Ceylanpınar-Sanlıurfa, in the southeast), denoting a semi- dry climate, to 92.2(Rize, in the northeast), denoting a very humid climate. The annual precipitation exceeds 2220 mm in Rize. Furthermore, there is not any region where $I_{DM}$ aridity index is less than 10 classified as dry since the evaporative demand cannot be met by precipitation. According to the index values, entire of the Central Anatolia, and a part of the eastern and Southeastern Anatolia regions are semi-dry. Spatial distribution of Pinna Index values have similar to De Martonne Index. A significant correlation was found between De Martonne and Pinna indices (the correlation coefficient is 0.91). Additionally, coastal areas present the humid and semi-humid climate. The percentage areas in monthly aridity conditions ($10\leq I_{DM}<20$) which semi -dry or need irrigated is 21% of the country. In these areas annual precipitation varied in between 200-400 mm. According to Pinna Combinative Index 9% of total stations in the country were found under the drought limits. The extreme locations which found by De Martonne Aridity Index were also addressed by the Pinna Combinative Index. There is a full agreement on the spatial classification between two indices. A significant relationship was found between the results for both index.

**Keywords:** Climate indices, precipitation and temperature patterns.

## 1. INTRODUCTION

Climate indices have been improved based mainly on several climate indicators such as heating degree days, precipitation, and aridity. Precipitation and temperature are most important parameters in climate studies. Climate indices studies were extensively studied in the literature (Smith, 1982, Conway et al., 1996, Jones et al., 1997, Baltas, 2007).

WALTER (1955); GAUSEN (1956); and BAGNOULS and GAUSEN (1957) proposed the temperature and precipitation as best bilateral parameters in determination of the climate parameters. Surface air temperatures were increased in Europe in the 20th century. The temperature increase has been maximum in the last quarter of the century (HOUGHTON et al., 2001; JONES et al., 1999b; KARL et al., 2000 and KLEİN et al., 2002). The continuous of heating were forecasted with variations in extreme climate events (FOLLAND et al., 1999; GROISMAN and Coauthors, 1999;NICHOLLS and MURREY, 1999, HAYLOCK and NICHOLLS, 2000). Recently some drought conditions and climatic variabilities in Turkey were analyzed (KÖMÜŞCÜ, A.U., 2001; KARACA et al., 2000; KADIOĞLU, M., 2000; TAYANÇ M. and TOROS, H., 1997 and TÜRKEŞ, M., 1996).

In this study, we focused on the spatial variation of climate indices which were used in determining of the climate structure of a region. De Martonne Aridity Index and the Pinna Combinative climatic indices were calculated over Turkey by using monthly temperature and precipitation in Turkey. The indices were compared with the topographical effects on the temperature and precipitation in Turkey.

## 2. DATA AND STUDY AREA

In this study, a total of 232 stations were examined for the calculation of the indices. The period of used slightly varied by station however it is covered 1960-2006. The monthly temperature and precipitation data for the period 1960-2006 at 232 stations were provided from Turkish State Meteorological Service (TSMS). Fig 1 shows the station locations.

Homogeneity has been assessed. Time series of the temperature and precipitation data in each station were tested. For this purpose Swed-Eisenhart Run test is used (Oliver, 1981).

Turkey is located in 36°- 42°N latitudes and, 26°-45°E longitudes. The country is surrounded by the Black Sea, Aegean Sea and Mediterranean Sea. The average altitude is 1130 m and gradually increases from central part to the east. A topographical map is given in Figure 2.

### *General climate in Turkey*

Turkey is situated over a transition region between polar and tropical air masses with Mediterranean climate characteristics in subtropical climate zone. In winter, the country is under the influences of polar front, cold air masses from Balkan Peninsula and lowest pressure area centered over Corsica and Sardinia in Mediterranean with frontal passages towards east. In summer, polar front is shifted to the north latitudes and consequently weak frontal passages and maritime effects are dominant.

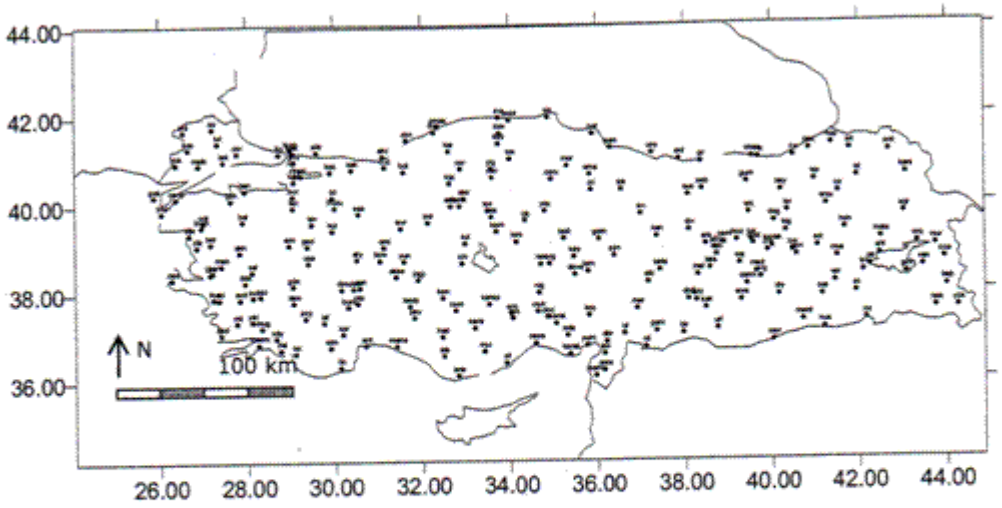


Figure 1: The locations of the meteorological stations over Turkey.

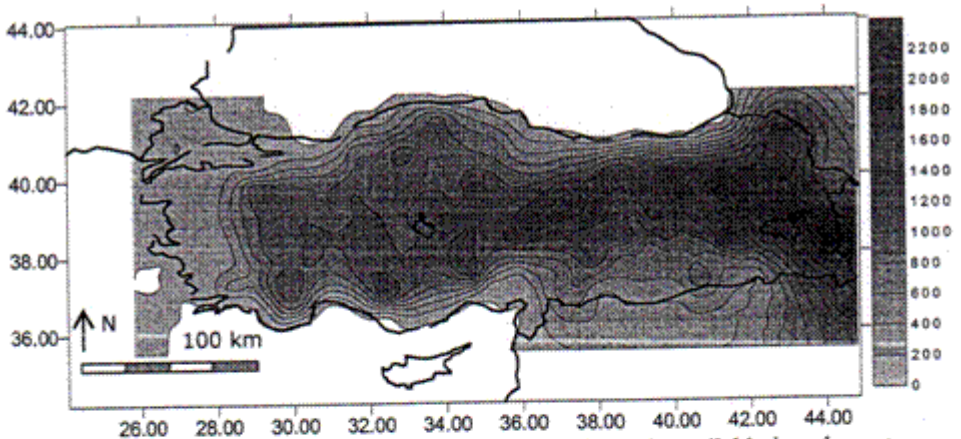


Figure 2: Topography of the study area (This figure is available in colour at www.bireygelisim.com/deniz/figures/spain/figure2.jpg)

Furthermore, topographic effects associated with the mountainous terrain in particularly greatly complicate the variability. Annual average rainfall in Turkey is around 630 mm. The wettest regions are the Eastern Black Sea coast where annual rainfall can reach 2300 mm. The driest regions in whole country are in Central Anatolia and Southeastern part of Turkey. Annual rainfall is less than 300 mm. The general climate characteristics have been examined in the literature (Türkeş, 1996; Tayanç et al., 1997; Kadıoğlu, 2000; Karaca et al., 2000, Kömüşcü, 2001). The understanding of atmospheric processes in Turkey and its different geographical regions is key point for research programs related to behavior of the temperature and precipitation regime.

## 3. DE MARTONNE ARIDITY INDEX

De Martonne aridity index ($I_{DM}$) is widely used for measuring aridity of an area. The Aridity Index of De Martonne (1941) is defined as the ratio of the annual precipitation sum PA in mm and annual mean temperature in C +10. The index is given by Eq.1

$$I_{DM} = \frac{P}{T + 10} \quad (1)$$

where, P is the mean annual precipitation (mm)and T is the mean air temperature (°C). According to $I_{DM}$ value, De Martonne classified the climate into six types (Table 1).

| Climate | Clas. Type | Values of $I_{DM}$ | | | Values of P(mm) | | | Number of Stations | |
|---|---|---|---|---|---|---|---|---|---|
| | | L1 | NOL1 | ratio (%) | L2 | NOL2 | ratio (%) | Both of NOL1 and NOL2 | ratio (%) |
| **Dry** | **0** | $I_{DM}$<10 | 0 | 0 | P<200 | 0 | 0 | 0 | 0 |
| **Semi-dry** | **1** | 10≤ $I_{DM}$<20 | 50 | 21 | 200≤ P<400 | 33 | 14 | 30 | 13 |
| **Mediterranean** | **2** | 20≤ $I_{DM}$<24 | 44 | 19 | 400≤ P<500 | 52 | 22 | 21 | 9 |
| **Semi-humid** | 3 | 24≤ $I_{DM}$<28 | 47 | 21 | 500≤ P<600 | 35 | 15 | 10 | 4 |
| **Humid** | 4 | 28≤ $I_{DM}$<35 | 47 | 20 | 600≤ P<700 | 34 | 15 | 10 | 5 |
| **Very humid** | 5 | $I_{DM}$≥35 | 43 | 19 | P≥700 | 77 | 34 | 40 | 17 |
| | | | 231 | | | 231 | | 111 | |

Table 1: DE MARTONNE INDEX CLIMATIC CLASSIFICATION (DE MARTONNE, 1941).

De Martonne Aridity index can be calculated as:

$$I_{DM} = \frac{12\ P'}{T' + 10} \quad (2)$$

Where P' and T' monthly mean values of precipitation and temperature respectively.

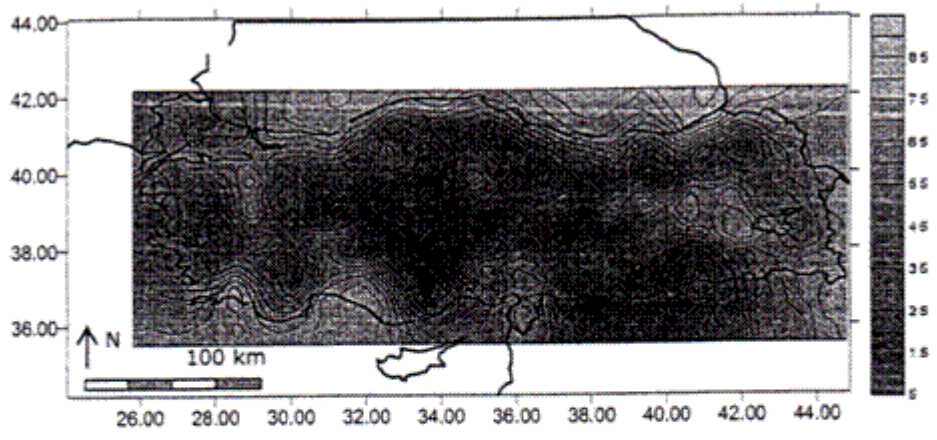


Figure 3: De Martonne Aridity Index in the study area (This figure is available in colour at www.bireygelisim.com/deniz/figures/spain/figure3.jpg)

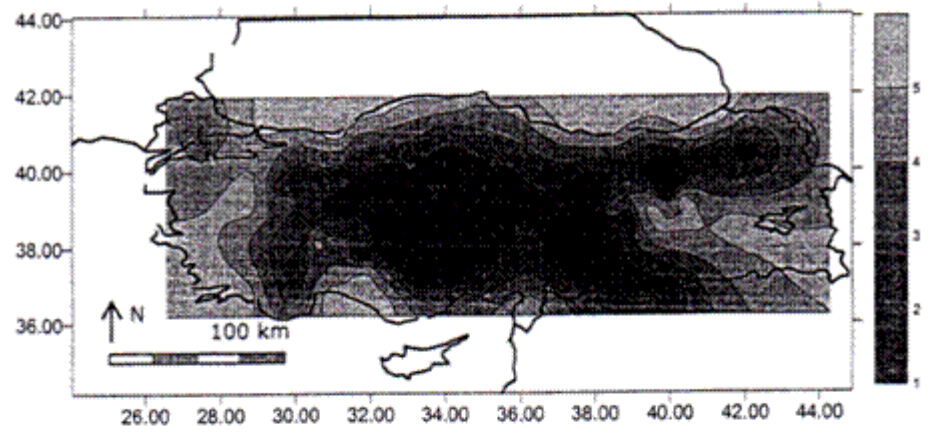


Figure 4: De Martonne climatic classification. 0:Dry, 1: Semi-dry, 2:Mediterranean, 3:Semi-humid, 4:Humid, 5:Very humid. (This figure is available in colour at www.bireygelisim.com/deniz/figures/spain/figure4.jpg)

## 4. PINNA COMBINATIVE INDEX

Pinna developed the combination index Ip (Zambakas, 1992):

$$I_p = \frac{1}{2}\left(\frac{P}{T+10} + \frac{12\,P_d'}{T_d'+10}\right) \qquad (3)$$

where P and T are the annual mean values of precipitation and air air temperature and $P_d'$, $T_d'$ are the mean values of precipitation and air temperature of the driest month. This index

describes in a better way the regions and seasons, where irrigation is necessary since it takes into account the precipitation and air temperature of the driest month.

When the value of the $I_p$ is less then 10 ($I_p < 10$) the climate is characterized as dry and when the value of $I_p$ varies between 10 and 20 ($10 \leq Ip \leq 20$) the climate is considered semi-dry, Mediterranean vegetation. The spatial variation of the Pinna Combinative Index values is shown in Figure 6.

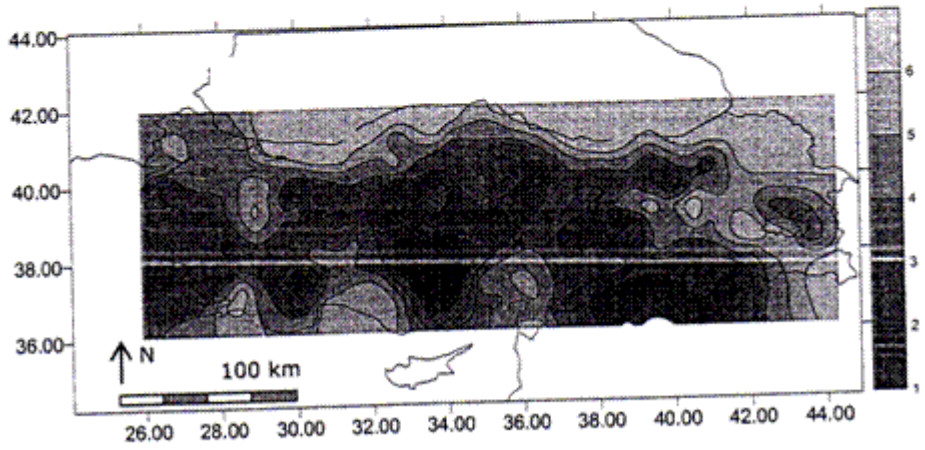


Figure 6: Pinna Combinative Index in the study area (This figure is available in colour at www.bireygelisim.com/deniz/figures/spain/figure6.jpg)

De Martonne Aridity and Pinna Combinative indices were compared. Figure 7 shows the correlations between De Martonne Aridity and Pinna Combinative indices. A significant correlation coefficient was found ($r^2$=0.91). Evaluating the results of the Aridity- Humidity indices of De Martonne and Pinna, De Martonne Index is more appropriate for the study area, since it defines more precisely the climate of each station. Its classification consists of six climate categories, ranging from dry to very humid, instead of just two categories of the Pinna Index.

## 5. CONCLUSIONS

The climate is an interactive system consisting of major components including atmosphere, hydrosphere, land surface and the biosphere, forced or influenced by various external forcing mechanisms. Therefore, understanding the variations in atmospheric processes and climate to meet economic, social and environmental needs are important.

Turkey is situated over a transition region between polar and tropical air masses with Mediterranean climate characteristics in subtropical climate zone. Furthermore, Turkey is surrounded by the Black Sea, Aegean Sea and the Mediterranean Sea. This situation increased the influencing the air-sea interaction. In this study, we present the results of Climate Classes based on De Martonne and Pinna indices using temperature and precipitation data from 232 stations for 47 years.

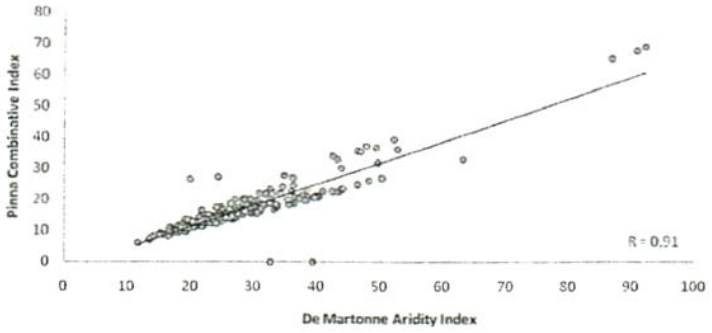


Figure 7: Statistical analysis between the indices of De Martonne and Pinna.

## 6. REFERENCES

BAGNOULS, F. AND GAUSSEN, H., 1957 : Les climats biologiques et leur classification. Annales De Geographie, 355, 193-220.

BALTAS, E., 2007: Spatial distribution of climatic indices in northern Greece, Meteorological Applicaitons. 14, 69-78.

CONWAY, D., WILBY, R.L. AND JONES, P.D., 1996: Precipitation and airflow indices over the British Isles, Climate Research, 7, 169-183.

FOLLAND, C.K. AND COAUTHORS, 1999: Workshop on indices and indicators for climate extremes, Asheville, NC, USA, 3-6 June 1997: Breakout Group C: Temperature indices for climate extremes. Climatic Change, 42, 31-43.

GAUSSEN, H., 1956: Le XVIII congress international de Geographie, Rio de Janeiro, Aout 1956. Annales De Geographie, 353, 1-19.

GROISMAN, P.Y. AND COAUTHORS, 1999: Changes in the probability of heavy precipitation: Important indicators of climatic change. Climatic Change, 43, 243-283.

HAYLOCK, M. AND NICHOLLS, 2000: Trends in extreme rainfall indices for an updated high quality dataset for Australia, 1910-1998, Int. J. Climatol., 20, 1533-1541.

HOUGHTON, J.T., DING, Y., GRISS, D.J., NOGUER, M., VAN DER LINDEN, P.J. AND XIAOSU, D., 2001: Climate change 2001: The Scientific Basic, Contrubution of Working Group I to Third Assesment Report of the Intergovermental Panel on Climate Change (IPCC). Cambridge University Pres, 944pp.

JONES, P.D., CONWAY, D. AND BRIFFA, K.R., 1997a: Precipitation variability and drought in Hulme, M and Barrow, E., Climates of the British Isles: present, past and future, Routledge, London, 197-219.

JONES, P.D., NEW, M., PARKER, D.E., MARTIN, S. AND RIGOR, G., 1999b: Surface air temperature and its changes over the past 150 years. Rev. Geophys. 37, 173-199.

KADIOĞLU M, 2000: Regional variability of seasonal precipitation over Turkey, International Journal of Turkey, 20, 1743-1760.

KARACA M, A.DENIZ AND M.TAYANC, 2000: Cyclone tracks variability over Turkey in association with regional climate, Int. J. of Climatol., 20, 1225-1236.

KARL, T.R., KNIGHT, R.W. AND BAKER, B., 2000: The record breaking global temperature of 1997 and 1998: Evidence for an increase in the rate of global warming? Geophys. Res. Lett., 27, 719-722.

KLEIN TANK, A. AND COAUTHORS, M.G., 2002: Daily dataset of 20th century surface air temperature and precipitation series for the European Climate Assesment. Int. J. Climatol., 22, 1441-1453.

KÖMÜŞCÜ, A.U., 2001: Analysis of the recent drought conditions in Turkey in relation to circulation patterns, Drought Network News, 13, 5-6.

NICHOLLS, N. AND MURRAY, W., 1999: Workshop on indices and indicators for climate extremes, Asheville, NC, USA, 3-6 June 1997: Breakout Group B: Precipitation, Climate Change, 42, 23-29.

OLIVER, J.E., 1981: Climatology: Selected Applications, Adward Arnold Ltd., 260 pp., London, UK.

SMITH, S.G., 1982: An index of windiness fort he United Kingdom, Meteorological Magazine, 111, 232-247.

TAYANÇ, M. AND TOROS, H., 1997: Urbanization effects on regional climate change in the case of four large cities of Turkey, Climatic Change, 35, 501-524.

TÜRKEŞ, M., 1996 b.: Meteorological drought in Turkey: A historical perspective, 1930-1993, Drought Network News, University of Nebraska, 8, 17-21.

WALTER, H., 1955: Die Klima – Diagramme als Mittel zur Beurteilung der Klimaverhtltnisse für kologische, vegatationskundliche und landwirtschaftliche Zwecke. Berichte der Deutschen Botanishen Gessellschaft, 68, 321-344.

ZAMBAKAS, J., 1992: General Climatology. Department of Geology, National and Kapodistrian University of Athens: Athens, Greece.