# ClimClass AND ClimClassMap: TWO R-PACKAGES FOR CLIMATIC AND AGRO-BIOCLIMATIC INDICES. AN APPLICATION TO TRENTINO
## *ClimClass E ClimClassMap: DUE LIBRERIE R PER IL CALCOLO DI INDICI CLIMATICI E AGRO-BIOCLIMATICI. UN'APPLICAZIONE AL TRENTINO*

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**Abstract**
Information required for climate classifications is usually simple: monthly means of temperature and precipitation. R-library ClimClass allows the calculation of the most widely climate classification – Köppen -  and of several indices of aridity and continentality. If a time series is available, the package can calculate Thornthwaite's water balance, and classify or compare climate at different sites with the relevant statistics. The graphical section of ClimClass plots three classes of diagrams: Bagnouls – Gaussen's, Péguy's, and the percentiles of a family of water balance variables. ClimClass also includes two functions for the calculation of agro-bioclimatic indices developed by the Intern. Organiz. of Grapevine and Wine (OIV). ClimClassMap applies some functions of ClimClass to raster objects, allowing to trace index maps. An application of some functions is proposed for Trentino, northern Italy; the comparison of two climate periods (1961-'90 and 1981-'10) allows to assess the climatic and bioclimac shift in the last decades.

**Keywords**
Climate classifications, indices, R, maps, Trentino
**Parole chiave**
Classificazioni climatiche, indici, R, mappe, Trentino

## Introduction
In Trentino, a mountain region in the Italian Alps, agriculture is widespread, and about 35% (apart pasture lands) is devoted to vineyards. Automatic climatic and bioclimatic classification can help to track both climatic differences among complex territory and index shifts between different periods.

## Materials and Methods
Monthly and daily gap-filled, homogenized series of temperature and precipitation at 29 stations were available from previous works (Eccel et al., 2012), supplied by E. Mach Foundation and Autonomous Province of Trento. They were averaged over two 30-year reference periods: 1981-'10 (for present climate) and 1961-'90 (for a comparison with the past standard).
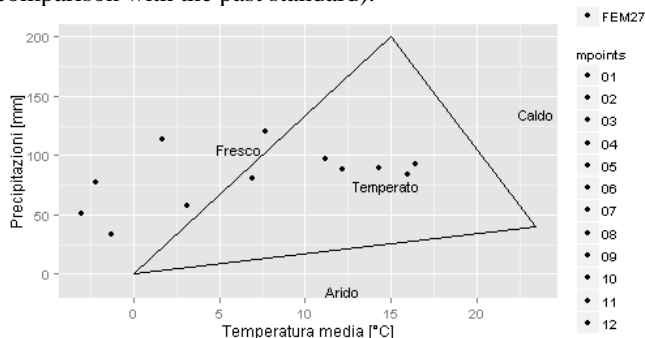


*Fig.1 –Péguy's chimograph, station of S. Michele*
*Fig.1 –Chimogramma di Péguy, stazione di S. Michele*

Two packages were developed in R open source environment: ClimClass (https://github.com/ecor/ClimClass, Eccel *et al.*, 2014) and ClimClassMap (https://github.com/ecor/ClimClassMap, to be contributed to R-Cran in 2015).
The former calculates Köppen's climate classification, six aridity indices, four continentality indices, Thornthwaite – Mather's water balance, and OIV's bio-climatic indices for
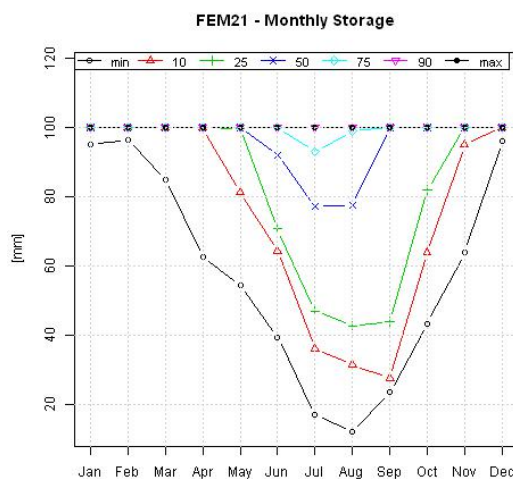


*Fig.2 – Soil water storage by Thornthwaite's model, percentiles over years in 1981-2010*
*Fig.2 – Immagazzinamento acqua nel suolo con il modello di Thornthwaite, percentili sugli anni 1981-2010*

vine growing. Some graphic functions allow straight-forward plots of Bagnouls – Gaussen's and Péguy's plots and water balances percentiles.

ClimClassMap package applies ClimClass' functions to raster objects producing raster maps.
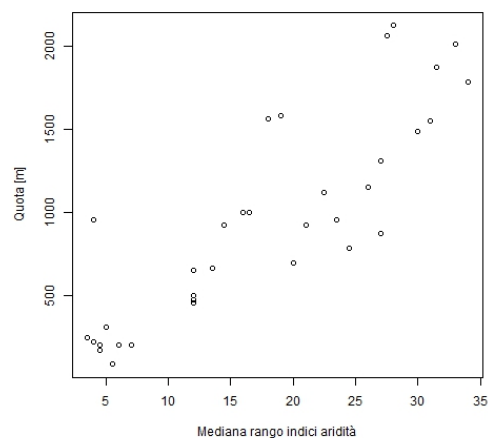


*Fig.3 – Median of ranks of all aridity indices vs. elevation*
*Fig.3 – Mediana dei ranghi di tutti gli indici di aridità in relazione alla quota*

## Results and Discussion

An example of Péguy's climograph is given in Fig. 1. An example of a quantile plot of soil water storage according to Thornthwaite and Mather's water balance model is represented in Fig. 2; several variables can be plotted with the specific function of package ClimClass.

Aridity indices showed a very good collinearity and a consistent trend with elevation; if ranks are used (to deal with all the different indices) a good correlation can be obtained (Fig. 3), yielding the expected result of less humid classes at the lowest elevation sites.

*Tab.1 – Class transition '81-'10 vs. '61-'90 of viticultural climate types according to Tonietto and Carbonneau (2004)*
*Tab. 1 - Transizioni di classe '81-'10 / '61-'90 dei tipi climatici viticoli secondo Tonietto and Carbonneau (2004).*

| ID | Huglin's heliotherimc index (HI) | | Cool Night Index (CI) | | Riou 's Drought Index (DI) | |
|---|---|---|---|---|---|---|
| | '61 - '90 | '81 - '10 | '61 - '90 | '81 - '10 | '61 - '90 | '81 - '10 |
| FEM21 / T0211 | HI-3 | HI-3 | CI+2 | CI+2 | DI-2 | DI-2 |
| FEM27 / T0038 | HI-1 | HI+1 | CI+1 | CI+1 | DI+1 | DI-1 |
| FEM30 / T0154 | HI+1 | HI+1 | CI+1 | CI+1 | DI-1 | DI-1 |
| FEM31 / T0083 | HI-2 | HI-2 | CI+2 | CI+2 | DI-1 | DI-1 |
| FEM52 / T0010 | HI-1 | HI+1 | CI+2 | CI+2 | DI-2 | DI-1 |
| FEM58 / T0090 | HI+1 | HI+1 | CI+2 | CI+2 | DI-1 | DI-1 |
| FEM67 / T0001 | HI-1 | HI-1 | CI+2 | CI+2 | DI-1 | DI-1 |
| T0014 | HI-3 | HI-3 | CI+2 | CI+2 | DI-2 | DI-2 |
| T0018 | HI-3 | HI-3 | CI+2 | CI+2 | DI-2 | DI-2 |
| T0129 | HI+1 | HI+1 | CI+1 | CI+1 | DI-1 | DI-1 |
| T0139 | HI-3 | HI-2 | CI+2 | CI+2 | DI-2 | DI-2 |
| T0147 | HI+1 | HI+2 | CI+1 | CI-1 | DI-1 | DI-1 |

When climate shift is indexed, a clear pattern is shown toward a warmer, more arid climate, while no major shift can be detected for continentality. This was assessed for both climatic and viticultural bio-climatic indices (the latter in Tab. 1, for 1981-'10 vs. 1961–'90, where orange is a transition to a warmer or drier class, blue is the opposite).

Finally, an application of ClimClassMap is given in Fig. 4, where the shift in De Martonne's aridity index is shown between the past (1961-'90) and the present (1981-'10) climate conditions. The mean value was only slightly negative (drier).
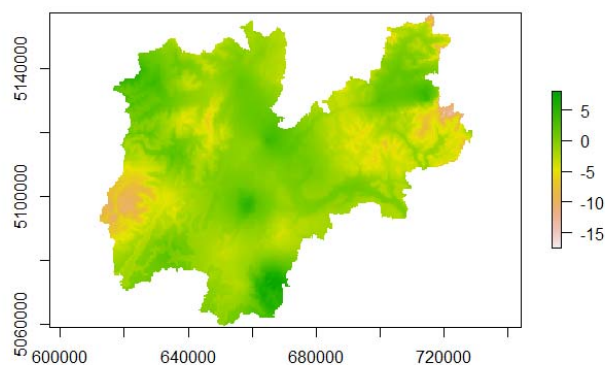


*Fig.4 – Climatic shift in De Martonne's annual aridity index. Positive: more humid. Negative: drier.*
*Fig.4 – Spostamento climatico dell'indice di aridità annuale di DeMartonne. Positivo: più umido. Negativo: più secco.*

## Conclusions

The two R packages ClimClass and ClimClassMap are useful tools for assessing climate and agro-climatic features at both single locations and areas. Their use is particularly recommended for viticultural zoning and for assessment of shift due to climate change.

## Acknowledgements

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