THE GEOVITICULTURE MCC SYSTEM

AND ITS INTERNATIONAL INTERNET SITE

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RESUMEN

El texto presenta el Sistema de Clasificación Climática Multicritério Geovitícola. Incluye los conceptos, metodologías y indices climáticos vitícolas, la página web internacional del Sistema CCM y aun bibliografías con diferenciados usos en el ámbito mundial. El Sistema ha sido utilizado para los estudios de los climas de las regiones vitícolas de los países iberoamericanos. En la pagina web del sistema http://www.cnpuv.embrapa.br/tecnologias/ccm/ se puede encontrar la información de referencia del Sistema.

1 INTRODUCTION

Climate is an important factor in viticulture in different regions of the world, influencing the characteristics of grapes and wines. Wine production in the world occurs in many types of climates. The Geoviticulture Multicriteria Climatic Classification (MCC) System was developed to improve the characterization of viticultural climate of the wine producing regions of the world.

Because it is multicriteria (3 separate viticultural climatic indexes), the MCC System broadened the characterization of climatic factors which affect the adaptation of varieties, grape quality (sugar, acidity, color, smell) and the typification of wines, which are not well discriminated by the monocriteria climatic indexes available so far.

This system is able to characterize the viticultural climate in any wine producing region and the climatic groups of worldwide viticulture, acting as a reference system for global viticulture and allowing comparisons of viticultural climates of different regions of the world.

2 THE METHODOLOGY OF THE MCC SYSTEM

The MCC System was described by Tonietto (1999; 2007) and by Tonietto & Carbonneau (2004), and the methodology was used to generate a database of worldwide viticultural climates. This System is composed of 3 viticultural climatic indexes, thus multicriteria, synthetic and complementary, including 3 concepts.

2.1 Concepts of the MCC System

The MCC System was conceived within the concept of Geoviticulture, which is the processing of the viticultural information in a worldwide scale (Carbonneau and Tonietto, 1998). Geoviticulture applied to climate makes it possible to identify and compare the viticultural climate of different regions, to characterize its worldwide variability and to establish climatic groups of grape producing regions with similar climatic potential. The three concepts of the system are:

2.1.1 Viticultural Climate

It is the climate of a vineyard, a locality, or a grape-growing region, described by the set of three viticultural climatic indexes. Considering that the meteorological conditions throughout vine cycle of a place changes from one year to another, we have 2 sub-definitions: "the viticultural climate (mean)" and "the range of the viticultural climate (vintages)".

2.1.2 Climatic Group

A climatic group (of vineyards, localities or grape-growing regions) is the set of vineyards, localities or viticultural regions that present the same class of viticultural climate.

2.1.3 Viticultural Climate with Intra-annual Variability

It is the viticultural climate of a region which, under natural conditions, changes viticultural climate class as a result of the time of year at which grapes can be produced (frequent in tropical and subtropical climates).

2.2 The viticultural climatic indexes of the System and classes of viticultural climate

The three viticultural climatic indexes (heliothermal, nictothermal, hydric) of the MCC System are: Heliothermal Index (HI), Cold Night Index (CI) and Dryness Index (DI).

2.2.1 Heliothermal Index

HI is a viticultural climatic index developed by Huglin (1978), which estimates the heliothermal potential of a specific climatic condition; temperature calculations consider the period of the day in which grapevine metabolism is more active; the index also includes a correction factor for the length of the day in higher latitudes. HI is related to the thermal requirements of grape varieties, and to potential sugar content of grapes.

Calculation: The Heliothermal Index of Huglin (HI) (Huglin, 1978) is calculated as follows:

$$HI = \sum_{01.Apr}^{30.Sep} \frac{(T-10)+(Tx-10)}{2} \cdot d$$

In the Northern Hemisphere in the above formula, T is the mean air temperature (°C); Tx is the maximum air temperature (°C); d is the length of day coefficient, ranging from 1.02 to 1.06 between 40° and 50° of latitude (Table 1).

In the Southern Hemisphere the index is calculated using the 6-month period from 1 October to 31 March instead.

The index is calculated from monthly climatic means.

Table 1. The length of day coefficient (d) for the HI index, according to the latitude.

Latitude	Length of day coefficient (d)
≤ 40°00'	1.00
40°01' - 42°00'	1.02
42°01' - 44°00'	1.03
44°01' - 46°00'	1.04
46°01' - 48°00'	1.05
48°01' - 50°00'	1.06

2.2.2 Cold Night Index

CI is a viticultural climate index developed to estimate the nictothermal condition associated with the grape maturation period (Tonietto, 1999; Tonietto & Carbonneau, 2004). Using minimum temperatures, the index serves as an indication of a region's potential characteristics with respect to secondary metabolites (polyphenols, aromas, color) in grapes and wines.

Calculation: The determination of the cool night index (CI) is done as given below (Tonietto, 1999):

In the Northern Hemisphere: CI = average daily minimum air temperature in the month of September (mean of minima), in °C.

In the Southern Hemisphere: CI = average daily minimum air temperature in the month of March (mean of minima), in °C.

2.2.3 Dryness Index

DI is a viticultural climatic index that characterizes the water component of a region, strongly related to the qualitative characteristics of grapes and wine. DI was adapted (Tonietto, 1999; Tonietto & Carbonneau, 2004) from the potential water balance of soil index of Riou (Riou et al., 1994). It takes into account the climatic demand of a standard vineyard, evaporation from bare soil, rainfall without deduction for surface runoff or drainage. It indicates the potential water availability in the soil, related to the level of dryness in a region.

Calculation: The potential water balance index of Riou was adapted for the calculation of the dryness index, using the formula (Tonietto & Carbonneau, 2004):

$$W = Wo + P - Tv - Es$$

where W is the estimate of the soil water reserve at the end of a given period, Wo is the initial useful soil water reserve which can be accessed by the roots, P is the precipitation, Tv is the potential transpiration in the vineyard, and Es is the direct evaporation from the soil during the period.

The Dryness index (DI) is calculated based on a 6-month period (the same period used for the calculation of HI, described above). The values of W at the first and last moment, and the initial and final date, for both hemispheres, are reported in Table 2.

The values of Tv and Es used for determining W are calculated monthly using:

$Tv = PET \cdot k$

where PET is the potential evapotranspiration (monthly total), using the Penman method (Penman, 1948) and k is the coefficient of radiation absorption by the vine plant (which is related to transpiration and depends on vine architecture)

$Es = PET \cdot (1 - k) \cdot JPm / N$

where N is the number of days in the month and JPm is the number of days of effective evaporation from the soil per month; for JPm estimation we use the rainfall per month in mm/5; JPm should be no higher than the number of days per month.

The values of k adopted are:

In the Northern Hemisphere, k = 0.1, for April, 0.3 for May and 0.5 from June to September.

In the Southern Hemisphere, k = 0.1 for October, 0.3 for November and 0.5 from December to March.

Table 2. Period for the calculation of DI and the value of W.

Moment	Date in the hemisphere		Value of W
	North	South	
Initial moment	1 April	1 October	W = initial Wo reserve
Final moment	30 September	31 March	W = DI

W can be negative, expressing the potential water deficit, but should not be greater than Wo. The index is calculated month by month, based on monthly values of P, PET, Tv and Es. DI is called the value of W obtained at the final moment following the rules above and using a starting value of Wo = 200 mm.

2.2.4 Classes of viticultural climate

The classes proposed for the different viticultural climate indexes are presented in the Table 3.

Table 3. Classes of viticultural climate for the dryness index, heliothermal index and cool night index of grape-growing regions.

Index	Class of viticultural climate	Acronym	Class interval	
Heliothermal index, HI	Very warm	HI + 3	>3000	
	Warm	HI + 2	>2400	≤3000
	Temperate warm	HI + 1	>2100	≤2400
	Temperate	HI - 1	>1800	≤2100
	Cool	HI - 2	>1500	≤1800
	Very cool	HI – 3		≤1500
Night cold index, CI (°C)	Very cool nights	CI + 2		≤12
	Cool nights	CI + 1	>12	≤14
	Temperate nights	CI - 1	>14	≤18
	Warm nights	CI - 2	>18	
Dryness index, DI (mm)	Very dry	DI + 2		≤ -100
	Moderately dry	DI + 1	> -100	≤50
	Sub-humid	DI - 1	>50	≤150
	Humid	DI - 2	>150	

3 THE INTERNATIONAL INTERNET SITE OF THE MCC SYSTEM

The International Internet Site of the MCC System is meant to enhance and potentialize the use of the Geoviticulture MCC System for the benefit and development of worldwide grape and wine production. It makes available information about the viticultural climate of wine producing regions in different countries of the world. It also shows results published using the methodology and tools of the MCC System.

The Internet website was created by Embrapa (Embrapa Uva e Vinho, 2007) to publish the MCC System and make the resulting viticultural climate database available for the international scientific community. Its intention is to make the data available for whichever purpose users may need it. The site may be accessed at the address http://www.cnpuv.embrapa.br/ccm.

The site briefly describes the Geoviticulture MCC System, providing online access to a database of climatic indexes in wine producing regions of the world. The site was written in HTML and PHP, and the data is stored in a MySQL database. The web server uses Apache running on a Debian Linux Platform. The web site is currently available in Portuguese, French and English.

The main page of the site describes the MCC System and its objectives and provides links to the other pages. It also lists the institutions which currently participate in the MCC System and provides information on how other institutions may contribute to the database. The Methodology page describes the three climatic indexes (Heliothermal Index - HI, Cold Night Index - CI, and Dryness Index - DI) and how they are calculated. It also lists the six classes of HI (ranging from -3 to +3) and their boundaries, as well as the four classes of CI and DI (ranging from -2 to +2). It also describes some important concepts of the MCC System.

The Database page allows the user to search for worldwide viticultural climatic indexes. Database search criteria allow displayed results to include all countries or be limited to one specific country. The search may also be limited or not to one of the six classes of HI, one of the four classes of CI or DI, or any combination of these search criteria. Results are displayed in alphabetical order and include country, viticultural region, meteorological station with latitude, longitude, altitude, HI value, CI value, DI value, HI class, CI class and DI class. Also included are the time period (years) used in determining the three indexes, during which climatic data was collected in each place, as well as a reference to the source from which the data was obtained.

In tropical regions, the seasons are not defined as rigidly as in a temperate climate, and grapes may be harvested throughout the year. In these places, the climatic indexes vary according to the time of harvest and a separate index was calculated for each month of potential harvest. The database entries relative to tropical places include these monthly indexes.

In order to make it easier to visually identify locations with similar viticultural climate according to the MCC System, an orthogonal color classification scheme within the RGB color space was used for the three indexes (Fialho & Tonietto, 2008). HI varies along the red-cyan axis, with red as the highest heliothermal (above 3000) and cyan as the lowest (below 1500), with a white midpoint at 2100. CI varies along the blue-yellow axis, with yellow as the warmest nights (above 18°C) and blue as the coldest (below 12°C), with a white midpoint at 14°C. DI varies along the green-magenta axis, with green as the most humid (above +150 mm) and magenta as the driest (below -100 mm), with a white midpoint at +50 mm.

The online Calculations page allows the user to calculate HI, CI and DI based on monthly climatic information supplied by the user about a viticultural region (mean, minimum and maximum temperatures, precipitation and potential evapotranspiration). It also determines the classes in which each of the three calculated indexes fall in, searches the database for locations with a similar viticultural climate and displays the list of these locations to the user.

The viticultural climate database includes, up to this date, over 20 countries and continues to grow. An example of database search results is shown on Figure 1, in which Brazil was selected as a search criteria. This example shows twelve entries for Petrolina (in the viticultural region of the São Francisco Valley), which is located in a tropical region, and has a viticultural climate with intra-annual variability, with a large variability in DI, characterizing a dry season and a wet season during the year. Also shown are seven other wine producing regions of Brazil, located in a subtropical climate with well defined growing seasons, which therefore do not have intra-annual variability.

The database may be used to compare the climates of different locations, as shown on Figure 2, which compares two wine producing regions, one in Brazil and the other in France. The graphs show differences between the geoviticultural indexes and the climatic variables important to their composition. The system may also be used to find locations with similar climates throughout the world.

An example of online viticultural climate index calculations (HI, CI and DI) is shown on Figure 3, which demonstrates how someone may use the website to determine the class of viticultural climate in the location of its vineyards. User input is divided into three categories. In the Identification section are the names of the viticultural region, weather station and country. The Geographic coordinates include latitude, longitude, altitude and the list of years which compose the time series of climatic data used (should be at least 10 years; preferably 30). The most significant section for the calculations is Monthly climatic data, in which values should be entered for each of the months of April through September (in the Northern Hemisphere) or October through March (in the Southern Hemisphere). These data include the monthly average of the daily minimum temperatures (only for the last month), the monthly averages of the daily maximum and mean temperatures, and monthly total precipitation and evapotranspiration.

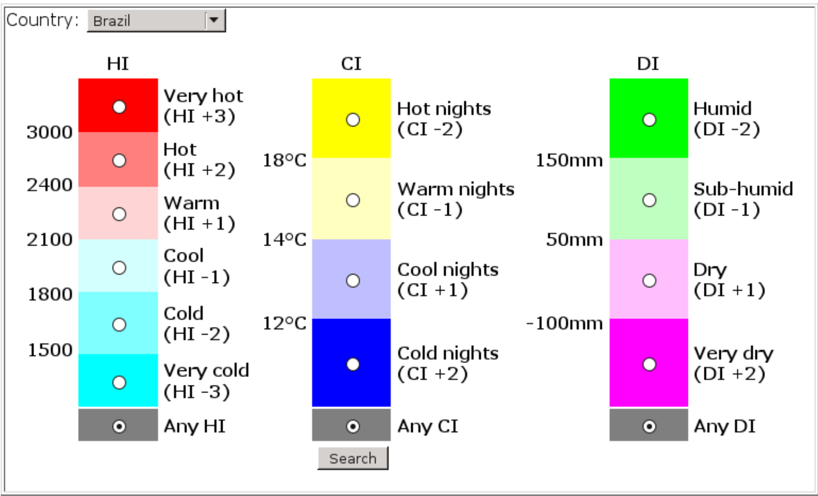
The results show a hypothetical location in the middle of the Atlantic Ocean with HI=2000 (class HI-1), CI=13°C (class CI+1) and DI=132mm (class DI-1), which is a viticultural climate similar to the French regions of Agen, Bordeaux, Cognac and Toulouse.

As global warming is becoming a reality, it is important to be able to predict its consequences in wine production. The MCC System may be used to simulate the effects of climate changes in viticultural climatic indexes. The database may then be searched in order to find which locations in the world have a climate similar to the expected future conditions, which may give hints about the changes that may be expected in viticultural potential related with wine characteristics.

Geoviticulture MCC System

Online search in the worldwide database

Note: This database of the vitivultural climate in wine producing regions of the worls is being updated and expanded. The aim is to include the greatest possible number of wine producing regions in different countries of the world. In order to participate in the Geoviticulture MCC System, please refer to the instructions on How to participate in the MCC System, within this website.



N	Country	Region		Position: Latitude	Position: Longitude	Position: Altitude	HI	CI (°C)	DI (mm)	Class: HI	Class: CI	Class: DI	Period	Source
1	Brazil	Campanha Meridional / Bagé		31°20'S	54°05'W	420m	2653	16.9	123	HI+2	CI-1	DI-1	1972-1997	[1]
2	Brazil	Campanha Setentrional / Quaraí		30°23'S	56°26'W	100m	2786	17.3	93	HI+2	CI-1	DI-1	1967-1990	[1]
3	Brazil	Campanha Setentrional / Uruguaiana		29°45'S	57°05'W	74m	2928	17.8	27	HI+2	CI-1	DI+1	1963-1990	[1]
4	Brazil	Campos de Cima da Serra / Vacaria		28°33'S	50°42'W	955m	2067	13.5	200	HI-1	CI+1	DI-2	1966-1990	[1]
5	Brazil	Planalto Catarinense / São Joaquim		28°17'S	49°55'W	1415m	1714	12.1	200	HI-2	CI+1	DI-2	1972-2001	[2]
6	Brazil	Serra do Sudeste / Encruzilhada do Sul		30°32'S	52°31'W	420m	2217	16.5	165	HI+1	CI-1	DI-2	1961-1990	[1]
7	Brazil	Serra Gaúcha / Vale dos Vinhedos		29°09'S	51°32'W	640m	2365	16.1	200	HI+1	CI-1	DI-2	1961-1990	[3]
8	Brazil	Vale do Submédio São Francisco*	1	9°09'S	40°22'W	366m	3659	21.3	-136	HI+3	CI-2	DI+2	1969-1993	[3]
			2				3650	21.6	-85	HI+3	CI-2	DI+1		
			3				3654	21.3	-1	HI+3	CI-2	DI+1		
			4				3563	21.0	46	HI+3	CI-2	DI+1		
			5				3490	20.0	51	HI+3	CI-2	DI-1		
			6				3376	18.8	43	HI+3	CI-2	DI+1		
			7				3289	18.1	8	HI+3	CI-2	DI+1		
			8				3298	18.7	-52	HI+3	CI-2	DI+1		
			9				3294	19.9	-110	HI+3	CI-2	DI+2		
			10				3385	21.3	-162	HI+3	CI-2	DI+2		
			11				3458	22.2	-182	HI+3	CI-2	DI+2		
			12				3572	21.7	-169	HI+3	CI-2	DI+2		

*Region of viticultural climate with intra-annual variability (1 = grape harvest in January, 2 = grape harvest in February, etc.)

References

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Figure 1. Output of a query to the worldwide viticultural climate database.

Geoviticulture MCC System

Location description

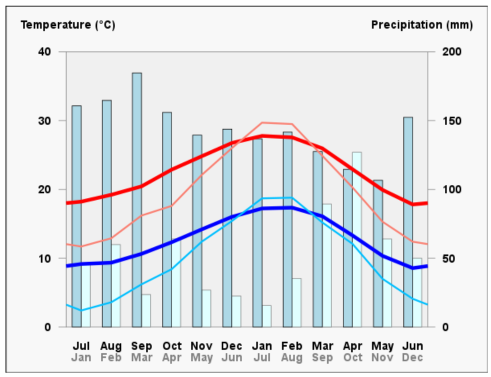
Brazil: Serra Gaúcha: Vale dos Vinhedos

- **City:** Bento Gonçalves
- **Weather station:** Embrapa Uva e Vinho
- **Latitude:** 29°09'S
- **Longitude:** 51°32'W
- **Altitude:** 640 m

Geoviticultural climatic indexes

HI	CI (°C)	DI (mm)	Classes		
			HI	CI	DI
2365	16.1	200	HI+1	CI-1	DI-2

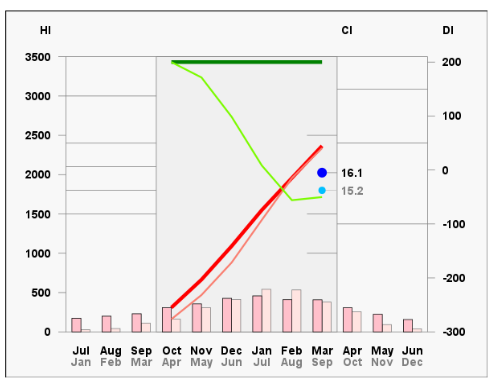
Average monthly temperatures (maximum and minimum) and precipitation



Compare with another region

France | Montpellier

Evolution of geoviticultural climatic indexes



Weather data

Month	Temperature			Precipitation	PET Penman-Monteith
	Minimum	Mean	Maximum		
Jan	17.23	21.76	27.78	136.83	141.32
Feb	17.35	21.68	27.56	141.63	118.63
Mar	16.10	20.32	25.97	127.52	107.63
Apr	13.32	17.46	22.94	114.54	69.08
May	10.34	14.51	19.93	106.63	47.37
Jun	8.56	12.64	17.81	152.39	36.46
Jul	9.16	12.94	18.22	160.73	43.70
Aug	9.35	13.64	19.22	164.68	57.89
Sep	10.63	14.92	20.44	184.67	78.17
Oct	12.32	17.01	22.87	155.92	113.24
Nov	14.19	18.92	24.82	139.46	129.50
Dec	16.01	20.74	26.75	143.78	147.99

Figure 2. Comparison of two geoviticultural climates.

Geoviticulture MCC System

Calculation of viticultural climatic indexes HI, CI and DI

Instructions: Fill the form below and click on ***Calculate***. The climatic data are for the months of October through March in the Southern Hemisphere or April through September in the Northern Hemisphere.

Identification

Name of the viticultural region:	Example region
Name of the weather station:	Example station
Country:	Nowhere

Geographic coordinates

Latitude:	45 ° 0 ' 0 " N
Longitude:	30 ° 0 ' 0 " W
Altitude:	0 m
Time series of interannual means:	1975-2005

Monthly climatic data (interannual means: 30 years, if available; minimum 10 years)

Month		Air temperature (°C)			Precipitation	Potential evapotranspiration (PET Penman-Monteith)
Hemisphere		Average minimum	Average maximum	Average mean	Monthly total (mm)	Monthly total (mm)
Southern	Northern					
October	April		24	14	50	100
November	May		25	15	50	100
December	June		26	16	50	100
January	July		27	17	50	100
February	August		26	16	50	100
March	September	13	25	15	50	100

Calculate

Results

HI	CI (°C)	DI (mm)	Class		
			HI	CI	DI
2000	13.0	132	HI-1	CI+1	DI-1

- Viticultural region: Example region
- Weather station: Example station
- Country: Nowhere
- Latitude: 45°0'0'' N
- Longitude: 30°0'0'' W
- Altitude: 0 m
- Time series: 1975-2005
- Minimum temperature in September: 13°C
- Maximum temperatures from April to September, °C: 24, 25, 26, 27, 26, 25
- Mean temperatures from April to September, °C: 14, 15, 16, 17, 16, 15
- Precipitation from April to September, mm: 50, 50, 50, 50, 50, 50
- PET from April to September, mm: 100, 100, 100, 100, 100, 100

Regions with the same viticultural climate class

N	Country	Region	Position			HI	CI (°C)	DI (mm)	Class			Period	Source
			Latitude	Longitude	Altitude				HI	CI	DI		
1	France	Agen	44°10'N	0°36'E	59m	1994	12.3	116	HI-1	CI+1	DI-1	1986-1995	[1]
2	France	Bordeaux	44°49'N	0°42'W	47m	1995	12.9	147	HI-1	CI+1	DI-1	1986-1995	[1]
3	France	Cognac	45°40'N	0°19'W	30m	1932	12.3	92	HI-1	CI+1	DI-1	1986-1995	[1]
4	France	Toulouse	43°37'N	1°22'E	151m	2042	13.4	79	HI-1	CI+1	DI-1	1986-1995	[1]

References

[1] TONIETTO, J. 1999. Les macroclimats viticoles mondiaux et l'influence du mésoclimat sur la typicité de la Syrah et du Muscat de Hambourg dans le sud de la France : méthodologie de caractérisation. (Thèse Doctorat). École Nationale Supérieure Agronomique de Montpellier - ENSA-M. 233p.

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Figure 3. Calculation of viticultural climate indexes HI, CI and DI.

Future developments of the website include the possibility of storing climatic data for each specific harvest and to evaluate the range of the viticultural climate in a specific location. This also makes it possible to compare climatic conditions of one harvest with another in the same location and to better characterize vintage wines. This may also be used to compare the viticultural climate of one year in one location with the viticultural climate of another year in a different location. The evolution of the indexes along the different months of the vegetative cycle may also be included in the future. This information will permit an analysis of the variation of the viticultural climate and improve the possibilities of comparing viticultural climates of different regions.

Perspectives for the future are to increase the quality and to enrich the climatic database by including data from more countries and more wine producing regions. A CYTED cooperation project involving 10 Ibero-American countries contributed to increase the database (Sotés and Tonietto, 2004). In these studies, the viticultural climate of the regions were presented using the model proposed in the Figure 4. The site will be constantly updated as new data becomes available for insertion in the database. The collaboration of new and current partners is crucial to this effect. New functionality is also being worked on, such as the estimation of the regional viticultural impact caused by climate change.

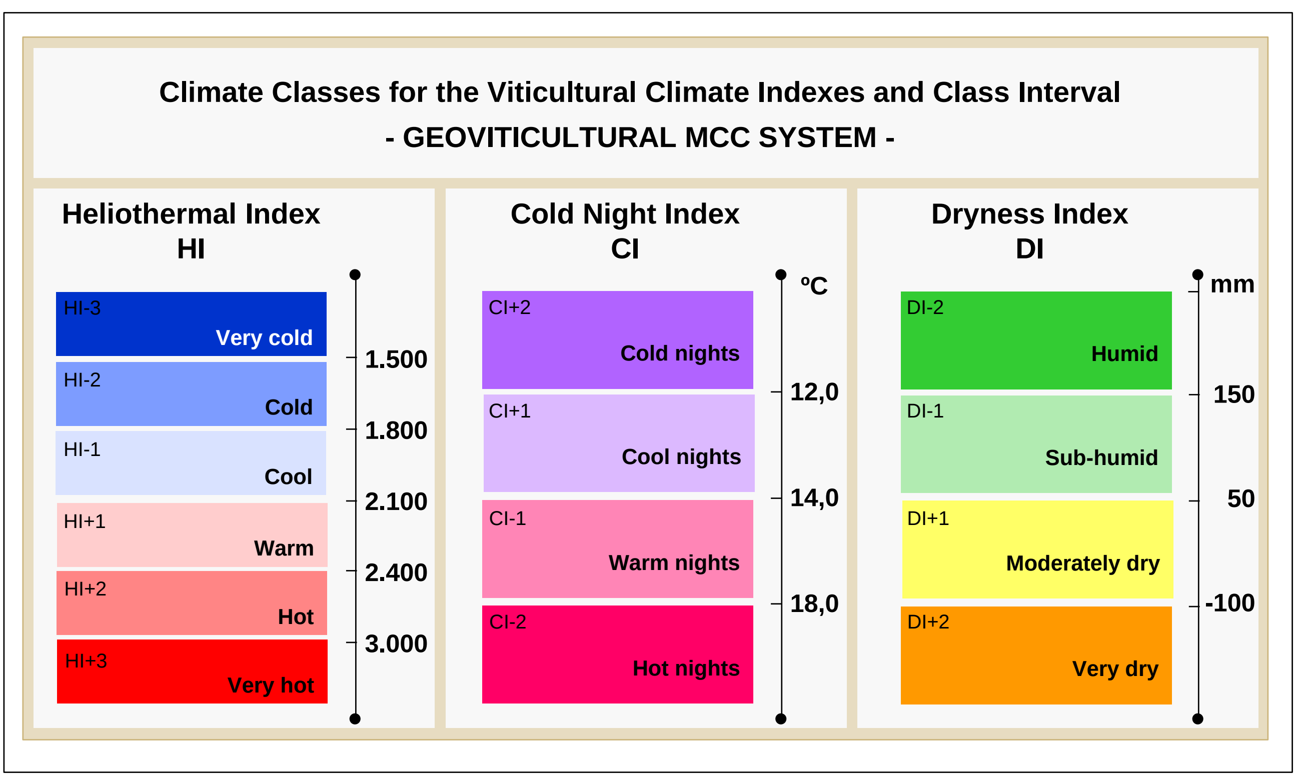

Figure 4. Model used in Ibero-American studies to describe viticultural climate with MCC System.

4 BIBLIOGRAPHY OF THE GEOVITICULTURE MCC SYSTEM

The Bibliography page in the site lists the literature references related to the MCC System (see below), providing, where copyrights permit, the full text in PDF for some of them:

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