CLIMATE AND MESOCLIMATE ZONIFICATION IN THE MIÑO VALLEY (GALICIA, NW SPAIN).

D. Blanco, C., Alvarez, M.P., García, and **J.M., Queijeiro**

Vigo University, Plant Biology and Soil Science Department, Ourense Science Faculty, As Lagoas s/n 32004 Ourense, Spain.
Email: dblancoward@uvigo.es

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Summary

Galicia is a region in Northwest Spain and has a long viticulture heritage. Today about 28,500 hectares are dedicated to vine growing and, of these, 8.100 has are protected under 5 distinct denominations of origin. Most of these zones are situated in the southern and central part of the region in and around the river Miño valley. Some high quality wines are also produced on the southwest coast and in the river Támega valley. The climate of this area is mild, fresh maritime with strong influences from the Atlantic which gradually give way to Mediterranean and continental inland tendencies as one goes inland to the East.

The main aim of this article is to demonstrate the suitability of the classification of today's Galician AOCs given the latest information on the field of Climatic Zoning.

For this purpose, standardized climate data provided by the Spanish and the Galician meteorological services have been utilized as well as data provided over the last five years by a new network of automatic weather posts that complete the previous network.

These data were used to calculate as series of climatic indices according to various methodologies. This information was later processed statistically to identify the most relevant factors in the differentiation of the vine growing areas.

Results confirmed the existence of four very clearly defined different viticulture climates. It was also shown that within the vine-growing zone of the Rías Baixas at least two sectors exist with quite distinct climatic conditions. Furthermore, the statistic processing of the information provided by the new automatic weather stations advanced research in climatic zoning permitting the identification of a series of typical mesoclimates that appear within the interior of the traditional viticulture zones.

Résumé

Galicia est une région située dans le Nord-Ouest de l'Espagne avec une longe tradition de culture de la vigne. A jour d'oui la vigne occupe en Galicia presque 28.500 ha, desquelles 8.100 correspondent aux 5 zones ayant droit à l'appellation DO (« Denominación de Origen ») équivalent aux AOC françaises. Les vignobles sont souvent localisés dans la partie moyenne et méridionale de la Vallée du Miño, bien que s'élaborent aussi vins de qualité dans les rivages atlantiques du sud-ouest et au val du Támega dans l'extrême sud-est. Le climat général est du type maritime tempéré avec d'influences océaniques que petit a petit sont remplacées pour des influences méditerranéennes et continentales, vers le sud et l'est de la région.

Le but de ce travail est évaluer les limites des DO galiciennes, en tenant conte l'évolution des techniques et indices de zonage climatique.

En préliminaire, les conditions climatiques ont été précisées d'un point de vue statistique (stations météo au sein des aires viticoles et stations limitrophes). Puis, plusieurs indices bioclimatiques proposées par la littérature vitivinicole ont été calcules. Le calcul a été opéré aussi sur les données apportées au cours des dernières 5 années pour le nouveau réseau de stations automatiques du Gouvernement régional.

L'élaboration et l'interprétation des résultats de l'analyse statistique ont permit de définir quatre zones agroclimatiques bien différentes au point de vue climatique. Ces résultats démontrent aussi que dans la DO Rías Baixas, il y a au moins deux zones avec conditions climatiques assez différentes. En outre,

les données apportées par les nouvelles stations automatiques, on permit d'identifier quelques zones climatiques similaires -à l'échelle de mesoclimat- à l'intérieur des DO traditionnelles.

Introduction

Situated in NW Spain, Galicia has a long-standing vine-growing tradition. Today vines are grown in more than 30.000 ha and of these some 8.300 ha are vineyards recognized officially by some of the five main AOCs present in the area and from which an average 250.000 hl of wine are produced per an.

Of the five AOCs registered in Galicia, three can be found in the Miño valley –namely Ribeiro, Ribeira Sacra and Valdeorras-. Some of the area of a fourth one –Rías Baixas- also lies in the estuary and final segment of the Miño valley closely separated from the Portuguese region of Vinhos Verdes cultivated along the south bank of this basin. Thus, only the smallest part of ours AOCs –that of Monterrei in the river Duero valley with 630 ha of vineyard today- does not belong within the Miño valley otherwise shared by most of the wine-producing areas of NW Spain.

The position of Galicia on the edge of the NW Atlantic shelf of the Iberian Peninsula means exposure to storms from the west and due to which we can speak of a cool climate under a strong maritime influence (Huetz, 1967). At the same time, the importance of relief should be taken into account and this could be described as a series of contours gradually increasing in altitude as one moves eastwards, although these so-called steps change when coinciding with mountainous zones running from North to South rising above surrounding relief. These ranges receive wet low-pressure fronts sweeping in from the sea bringing static rains and giving rise to rain shadows affecting various vine-growing areas.

Logically, this maritime character decreases little by little as one leaves the coast and moves eastwards. This change is clearly perceptible in the Miño valley with its alignment of 245º and where the maritime influence gives way to more Mediterranean characteristics as we penetrate inland and which can be seen in Table 1.

In the light of this data we can speak of a mild humid climate corresponding to Koeppen's Cf and Cs –mild, humid both with and without a dry season- and which some authors such as Gladstones (1992) recognize as the most adequate for the production of quality wines and therefore very similar to conditions reigning in many of the world's most prestigious viticultural areas. Evidently different sectors should be distinguished within this general description because the climate in areas at the end of the Miño valley where rain abounds -albeit when vines are at vegetative rest- differs from that of the AOCs lying in the central or eastern part of the valley where there are frequent and occasionally prolonged summer droughts.

These differences affect both yield and quality in the vineyards which in sectors close to the sea depend largely on the first early autumn rains and fungi diseases which affect ripening. In sectors situated further to the East the main problems are principally related to summer drought limiting production and at times even the quality of the harvest.

The coexistence of five different AOCs in a reduced territory is due to historic reasons and tradition as well as a series of influential characteristics such as topography, type of viticulture, type of wine, varieties utilized etc. all of which, logically, can be appreciated in the personality of the wines from each zone. Thus, for example, as for varieties a series of vinifers can be distinguished in almost all of the AOCs –Palomino and Grenache- which are generally considered less appropriate to make quality table wines and other more typical wines or of some specifically concrete AOC (Alvariño in the Rías Baixas AOC, the Ribeiro Treixadura, Mencia and Godello in the Ribeira Sacra and Valdeorras AOCs, and Dona Branca in Monterrei). Some of these are considered autochthonous although their presence is not exclusively limited to these sectors.

As in many other wine-growing and wine-producing areas of Europe, there is a current effort to restructure which has, among other things, a certain homogenising effect because significant areas are being planted with supposedly local varieties without all that much information to guarantee their complete adaptation to new conditions.

In order to complete this lack of information we proposed finding out more about possibilities offered by recent climatic indices developed specifically for vineyards (Gladstones 1992, Tonietto and Carbonneau, 2000; Carbonneau 2003) to identify and characterize the mesoclimates present in the Miño valley as a first step aimed to study the adaptation of indigenous varieties to these different mesoclimates.

We were aware that no generally valid indices were available and of the consequent need to identify or even to design the necessary parameters or climatic indices most suitable for this particular part of the Spanish peninsula. Investigation proved that there were different mesoclimates in the Miño basin and all that was needed was to identify the parameters or climatic indices required in order to distinguish them. Then once identified it would be relatively simple to set up an initial climatic zonification. This could then be completed with appropriate phenological data (i.e. mainly precocity and the length of cycles) as well as maturity of the different varieties (and in what way this is influenced by geographic factors such as altitude, and topographic aspect) so as to obtain some recommendations or general advice on the most suitable varieties for each area.

Materials and Methods.

For the setting out of climatic indices standardised data corresponding to a 30 year period was used from more than 40 weather stations forming part of the network of Meteorological stations belonging to the Spanish Institute of Meteorology and the Galician meteorological service. The stations were selected with the help of a cartographic package –GeoMedia 5.1 © - so that we were able to select those stations situated in or near the Galician AOCs. Distance of the stations from the sea was also computed with the help of GeoMedia 5.1 ©. Where necessary, the data were completed with information from bibliography (Carballeira *et al.*, 1983).
Some of the stations presented gaps in their meteorological series. Where possible, they were filled in with the establishment of reference stations –Lourizan and Ourense- which underwent an absolute homogenization by using Anclim algorithms (Štìpánek, P. 2004). By means of these data a series of climatic indices were calculated which are used in different wine growing areas in order to identify and characterize mesoclimates present in different parts of the world (Amerine and Winkler, 1944; Brañas *et al.*, 1946; Hidalgo, 1980; Huglin, 1978; Yglesias, 1983; Glasdtones, 1992; Tonietto y Carbonneau, 2000; Gómez-Miguel and Sotés, 2003).
The climatic data plus climatic indices obtained were then processed statistically by means of a principal component analysis using the statistics software SPSS 12 © in order to identify the most suitable indices and parameters for definition and characterization of the Miño valley mesoclimates.

Results and discussion

Table 1 shows some geographic details and climatic factors from twenty-four selected stations consulted for this study. These stations are located both in the Miño valley and in other nearby vine-growing areas. The data included in Table 1 confirm that the maritime character typical of the more westerly weather stations gives way to more mediterranean characteristics the further one proceeds up the Miño valley leaving the sea behind. This change can be appreciated regarding rainfall data (both mean annual rainfall as well as winter rainfall can duplicate and even triplicate rain measured in the most easterly weather stations) and also considering variations in the range of temperature (there can be up to 7ºC difference between coastline and inland stations) or during the frost free period. These data were used to calculate a series of climatic indices which various authors have used for the identification and classification of vine-growing climates.
Table 2 shows the values corresponding to the different climatic indices for each one of the stations selected in this study. These indices have been used by different researchers to characterize viticultural climates in several parts of the world.
The statistical analysis performed over the climatic parameters and indices showed high correlations among some of the figures as can be found in Table 3. The statistic processing included an analysis of principal components as well. Its results are summarized in Table 4 where the most useful climatic factors related to the identification and description of the climatic types present in the geography of wine production are seen to be fundamentally: mean annual rainfall (Map), temperature during growing period –from April to the end of September-, the effective temperature during the growing period (Et: sum of temperatures above 10ºC), the length of the period free from mean frosts (Ffp: time period when mean temperatures are above 0ºC), and the integral of effective temperatures (Iet).
As to climatic indices, we can indicate the outstandingly useful results of the Brana's hydrothermic index which (Hid) is the sum up of the product between monthly mean temperature and monthly rainfall from April to September, the Giacobbe index (Gia) with information on Summer drought, the

De Martonne aridity index (DM) which relates July and August rainfall with their mean maximum temperatures, the effective thermal integral which is the sum of mean temperatures above 10˚ C for the period which goes from April 1^{st} to September 30^{th}, Hidalgo index (Hig) which relates effective temperatures and day length during growing period with annual rainfall, the night freshness index (Nfi) which is the mean of minimum temperatures a month before harvest, and the Huglin index (Hug) providing indices of efficient temperature in relation to daylight duration.
The analysis of variance shows that 41,3% of the variability is related to a first component that basically includes variables related to rainfall (average annual rainfall, rainfall during active period) and to indices relating rainfall to temperature: Branas' hydrothermic index, De Martonne index, Davitaja index (Dav), Giacobbe's dry season index and Hidalgo index. Details related to temperature (sum of effective temperature and the average temperature over the active period, integral of effective temperature) and the indices based on temperature (Brana's heliothermic index and Huglin's index) are grouped as a second component accounting for about 38,3% of the variability. The third component conveys an additional 8,5% and is connected to the annual temperature range, the frost-free period and the night freshness index above all.
Using all three components three dimensionally to represent the meteorological stations consulted in this study we can obtain a spatial distribution as appears in Fig. 1 where four distinct weather station groups are shown and which can be associated to different types of climate.
A first climatic group would include all the weather stations located in the Sil river valley (where the Ribeira Sacra and Valdeorras AOCs are located) and the upper Duero basin (Monterrey AOC). These stations are characterized by their distance from the sea with a more continental climate with less rainfall and higher temperature ranges.
A second group would include those stations located within the Ribeiro AOC which are also located to the east of the Galician mountain chain and leeward from the storms which arrive from the sea. Almost all of the other stations belong to the Rías Baixas AOC and are located to the west of the Galician Mountain Chain albeit they can present quite different climates. Thus, there are stations which belong to the Tea county which have in common their winward location and their distance from the sea which translates into a shorter frost-free period and a larger temperatura range. Last, there is a group of coastal stations belonging to the O Salnes and O Rosal counties which characterize by a small annual temperature range and their lack of frosts.

Conclusions

These results confirm the existence of four distinct climatic zones. These results also confirm that two different mesoclimates within the Rías Baixas AOC can be clearly distinguished: one of them is located in areas close to the sea whereas the other is related with zones to the west of Galician Dorsal Mountains. These last stations are closer in their characteristics to the stations located in the Ribeiro AOC. All of the other AOCs present in the Miño valley are rather similar with respect to their climate because in all of them their maritime character becomes less significant with respect to their mediterranean component as one progresses towards the east.

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Tables and figures

Table 1.- Geographic details and climatic considerations from the meteorological stations consulted.

Station	Abb	Ds	Alt	Mat	Et	Atr	Map	Mp	Ffp
Vilagarcía	(Vlg)	2,0	36	15,0	1833,3	10,8	1580	481	365
Vilariño	(Vla)	1,9	60	15,3	1946,9	11,3	1393	400	365
Caldas	(Cal)	22,3	24	13,7	1454,2	11,4	1867	574	260
Ribadumia	(Rib)	6,9	65	14,8	1771,4	11,2	1582	481	342
Dean	(Dea)	1,6	20	14,0	1496,4	10,3	1602	470	327
Meís	(Mei)	17,0	115	14,6	1713,4	11,2	1941	588	363
Sanxenxo	(San)	0,2	20	15,5	2000,2	9,6	1398	444	365
Ponteareas	(Pon)	61,1	50	14,7	1787,3	12,7	1597	462	274
Guillarei	(Gui)	31,6	45	15,0	1888,8	12,5	1672	477	274
O Rosal	(Ros)	10,9	50	15,1	1757,8	11,2	1681	497	323
As Eiras	(Eir)	11,6	60	14,2	1595,9	11,0	1769	476	312
Lourizan	(Lou)	0,5	60	14,5	1662,6	11,0	1775	530	365
Fontefiz	(Fon)	126,6	200	13,8	1630,3	15,4	1420	431	259
Ourense	(Our)	115,3	148	14,8	1892,6	14,6	835	276	255
Leiro	(Lei)	110,5	110	13,4	1490,7	13,6	1481	389	211
Quinza	(Qui)	104,4	108	13,7	1560,2	13,2	1484	402	229
Prado	(Para)	108,8	145	14,1	1693,4	14,1	1181	289	260
Barbantes	(Bar)	116,2	120	13,9	1626,9	13,9	1217	368	226
Vilamartín	(Vlm)	225,9	312	13,7	1635,3	14,9	645	212	229
Larouco	(Lar)	224,2	530	12,8	1390,2	15,0	677	216	223
C.Caldelas	(Cal)	164,9	486	13,6	1538,2	12,8	662	259	230
Verín	(Ver)	166,4	407	12,8	1398,1	14,7	1114	330	202
Barco	(Bar)	237,4	410	13,7	1515,4	15,1	1106	314	201

Ds: distance in kilometers from the sea; Alt: altitude above sea level in meters; Mat: mean annual temperature (ºC); Et: sum of effective temperatures (Tª>10 ºC); Atr: average annual temperature range (ºC); Map: mean annual rainfall (mm); Mp: mean rainfall in mm from April to September (mm); Ffp: duration in days of frost free period with more than a minimum temperature over 0 º C.

Table 2.- Climatic indices corresponding to the meteorological stations consulted.

Stations	Hug	Hid	Dav	DM	Tap	Gia	Iet	Hig	Hel	Nfi
Vilagarcía	2186	6141	4,9	15,4	17,6	5,3	1452	23,7	3,7	14,0
Vilariño	2301	5891	4,0	14,7	17,9	5,1	1517	28,1	3,9	14,6
Caldas	2145	6850	6,2	18,6	16,4	6,2	1250	17,3	3,2	11,3
Ribadumia	2212	6093	4,7	14,0	17,4	5,0	1423	23,2	3,7	13,4
Dean	1921	5935	4,4	17,3	16,5	6,0	1252	20,2	3,2	12,8
Meís	2214	7354	5,4	19,4	17,3	6,8	1362	18,1	3,5	13,3
Sanxenxo	2184	5978	3,8	14,0	17,8	5,1	1493	27,7	3,9	14,8
Ponteareas	2431	5810	4,7	12,1	17,8	4,1	1500	24,2	3,9	11,9
Guillarei	2490	6110	4,6	13,3	18,1	4,4	1568	24,1	4,0	13,1
O Rosal	2214	6067	5,5	14,4	17,4	4,9	1418	21,7	3,6	13,0
As Eiras	2073	5635	5,8	14,2	16,9	5,4	1325	19,2	3,4	13,0
Lourizan	2140	6655	5,5	17,2	17,0	4,6	1347	19,6	3,5	12,7
Fontefiz	2488	5629	4,2	13,9	17,5	4,4	1465	26,6	3,8	11,1
Ourense	2625	3702	2,7	7,9	18,4	2,3	1638	50,7	4,2	12,3
Leiro	2262	5312	2,9	14,2	16,8	4,1	1336	21,8	3,4	10,0
Quinza	2389	5992	3,5	16,0	17,1	4,6	1377	24,2	3,6	10,1
Prado	2465	3888	2,3	8,0	17,6	2,6	1483	32,4	3,8	11,5
Barbantes	2449	4956	3,5	14,2	17,4	3,9	1438	28,0	3,7	10,9
Coles	2058	4634	4,0	13,9	16,4	3,9	1275	25,9	3,3	12,4
Vilamartín	2414	2949	1,9	7,3	17,5	2,2	1469	59,0	3,8	11,0
Larouco	2118	2646	2,3	8,1	16,5	2,2	1286	49,1	3,3	11,4
Castro	2231	3612	2,4	9,4	17,0	3,7	1361	53,1	3,5	11,9
Verín	2271	4010	4,0	8,6	16,5	2,8	1296	30,0	3,3	9,0
Barco	2338	4001	2,8	8,2	17,0	3,0	1383	32,3	3,6	10,7

Hug: Huglin's index; Hid: Branas´ Hydrothermic Index; Dav: Davitaja´s index; DM: De Martonne´s Index; Tap: Temperature of Active Period; Gia: Giacobbe Index; Iet: Integral of effective temperatures; Hig: Hidalgo´s Index; Hel: Heliothermic Index; Nfi: Night Freshness Index.

Table 3.- Correlation and significance matrices (* 95% significance)

Cor.	Mat	Et	Atr	Map	Mp	Ffp	Hug	Hid	Dav	DM	Tap	Gia	Iet	Hig	Hel	Nif
Mat	1	,94*	-,66*	,45*	,48*	,77*	,16	,55*	,39	,32*	,77*	,44*	,66*	-,28	,66*	,81*
Et		1	-,44*	,22	,25	.61*	,40*	,35*	,15*	,10	,92*	,20	,84*	-,06	,84*	,71*
Atr			1	-,68*	-,74*	-,85*	,55*	-,75*	-,68*	-,70*	-,07	-,82*	,09	,57*	,09	-,75*
Map				1	,97*	,60*	-,31	,95*	,90*	,86*	-,02	,85*	-,16	-,94*	-,16	,36
Mp					1	,67*	-,35*	,97*	,93*	,90*	-,01	,90*	-,16	-,88*	-,16	,44
Ffp						1	-,39*	,68*	,61*	,61*	,30	,69*	,14	-,47*	,15	,89*
Hug.							1	-,26	-,41*	-,45*	,71*	-,50*	,79*	,36	,79*	-,28
Hid.								1	,85*	,92*	,10	,91*	-,06	-,87*	-,06	,46
Dav.									1	,79*	-,10	,81*	-,23	-,81*	-,24	,40
DM										1	-,16	,93*	-,30	-,81*	-,30	,38
Tap											1	-,09	,98*	,16	,98*	,45
Gia												1	-,26	-,77*	-,26	,52*
Iet													1	,28	1,0*	,32
Hig														1	,28	-,22
Hel															1	,32
Nfi																1

Table 4.- Matrix of rotated components

Items	Mat	Et	Atr	Map	Mp	Ffp	Hug	Hid	Dav	DM	Tac	Gia	ITe	Hig	Hel	Nif
PCA1				.97	.95			.95	.88	.88		.84		-.93		
PCA2		.86					.80				.98		.98		.98	
PCA3			-.76			.82										.90

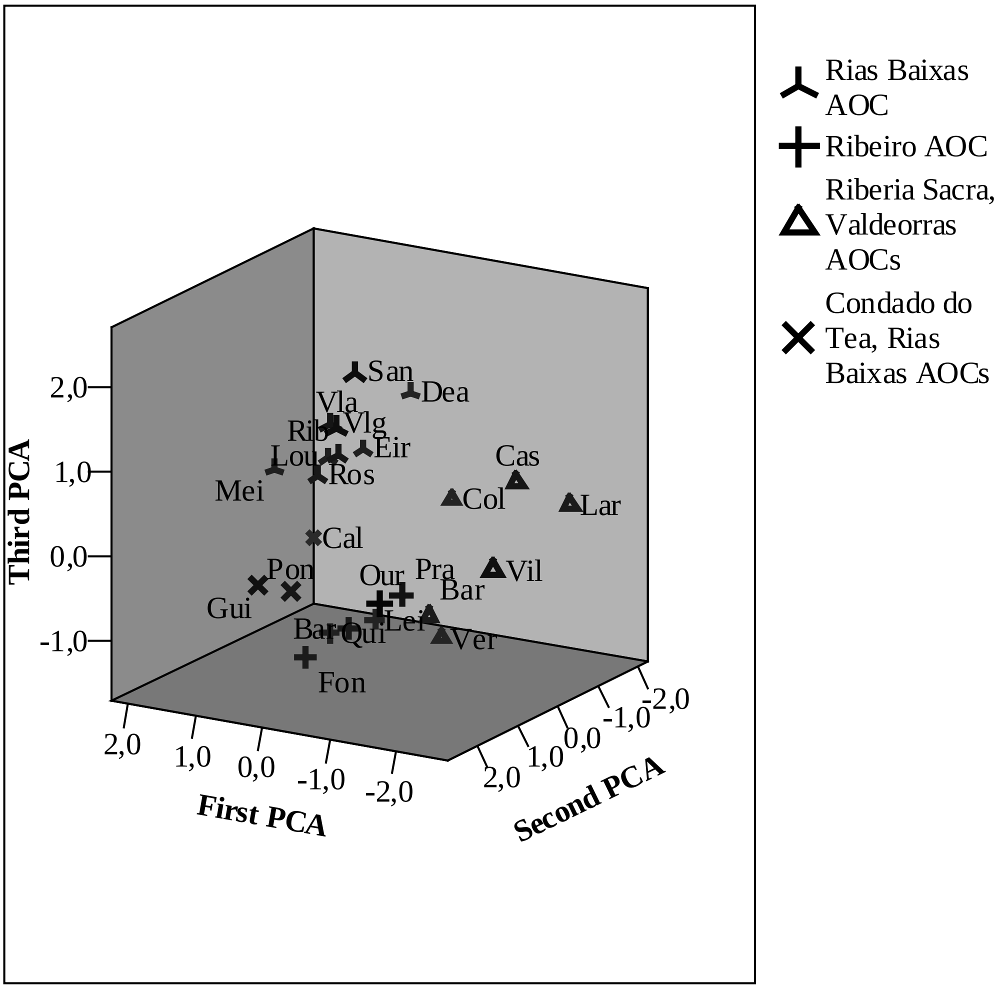

Figure 1.- Three dimensional diagram displaying the location of each weather station with respect to the first three ACP factors.