SOLAR RADIATION IN THE URUGUAYAN COAST OF THE RÍO DE LA PLATA AND ITS RELATION TO VITICULTURE CLIMATE INDICES

DISTRIBUTION DU RAYONNEMENT SOLAIRE DANS LA CÔTE URUGUAYENNE DU RIO DE LA PLATA ET SA RELATION AVEC LES INDICES CLIMATIQUES VITICOLES

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Abstract

The magnitude and distribution of solar radiation have an important impact in yield and vintage composition. In this study we analyzed solar radiation levels in the uruguayan coast of the Río de la Plata in relation with the viticultural climate indices. Its relationship with other meteorological variables was also investigated. The hourly solar irradiation at ground surface was obtained using a satellite-based model for six vineyards' locations. The model is a modification of a pre-existing statistical model (Justus et al., 1986) that was especially adapted for Uruguay's territory and surrounding areas using quality controlled radiation measurements (Alonso Suárez et al.,2012). Solar radiation data were generated for the four vintages (2011 to 2014) that were studied. The viticultural climate indices were calculated according to the Geoviticulture MCC System, adapted to Uruguayan conditions.

Results show a decreasing trend of solar radiation in the West-East direction. This trend was more pronounced during the summer season. The accumulated values of solar radiation during the growing cycle showed high correlation (Pearson's coefficients) with the following variables: Penman's potential evapotranspiration(r=0,90), heliophany (r=0,84), maximum air temperature(r=0,69),mean air temperature (r=0,62), accumulated rainfall (r=-0,83), relative air humidity(r= -0.63), Heliothermal index (HI), r=0,74) and Growing Degree Days (GDD10) (r=0,65). The Dryness index (SI) showed high correlation with irradiation in February (r = -0,64), while no correlation with the Cool Night index (FI) was observed. All correlation coefficients were highly significant, with p-values lesser than 0.0001. The determination of regional "profiles" of solar radiation can be used as a tool to delimit viticultural site, adjust cultural practices and characterize vintages'.

Keywords: *solar radiation, viticulture, climate classification, Rio de la Plata, terroir.*

Résumé

L'amplitude et la distribution du rayonnement solaire ont une grande importance pour la composition du vin. Nous avons analysé la relation qui existe entre le niveau de rayonnements solaires sur la côte uruguayenne du Rio de la Plata et les indices climatiques viticoles. Des relations avec d'autres variables météorologiques ont aussi été recherchées. Les radiations solaires ont été déterminées en fonction de l'heure au niveau du sol à l'aide d'un modèle et de données satellitaires dans six vignobles. Le modèle provient d'une modification d'un modèle statistique préexistant (Justus et al., 1986), les ajustements ayant surtout consisté à mieux l'adapter aux conditions de l'Uruguay et des territoires environnants à l'aide de mesures de radiations très bien contrôlées (Alonso Suárez et al., 2012). Pour cela, des données de radiations solaires ont été déterminées dans quatre millésimes (2011 a 2014). Les indices viticoles du climat ont été obtenus en utilisant le système Geo viticulture MCC, adapté aux conditions uruguayennes.

Les résultats ont montré qu'il existe une décroissance des radiations solaires de l'ouest vers l'est. Cette tendance est plus prononcée en été. Les valeurs cumulées de radiations solaires durant le cycle de production ont montré une forte corrélation (coefficients de Pearson) avec les variables suivantes: potentiel d'évapotranspiration de Penman (r=0,90), degré d'ensoleillement (r=0,84), température maximum de l'air (r=0,69), température moyenne de l'air (r=0,62), pluviométrie cumulée (r=-0,83), humidité relative de l'air (r= -0.63), indice héliothermique (HI) (r=0,74) et degré de croissance journalière (GDD10) (r=0,65). L'indice de sécheresse (SI) a montré une forte corrélation avec les radiations en février (r = -0,64), tandis qu'aucune corrélation n'a été enregistrée avec l'indice de fraicheur des nuits (FI). Pour tous ces coefficients de corrélation, la valeur de « p » a été inférieure à 0,0001. La détermination de "profiles" régionaux de radiations solaires peut être utilisée comme outil pour délimiter les terroirs viticoles, améliorer les techniques de culture et caractériser les millesimes.

Mots clés **:** *rayonnement solaire, viticulture, classification des climats, Rio de la Plata, terroir*

1-Introduction

More than 90% of the viticultural surface of Uruguay is located in the South of the country, on the coasts of the Río de la Plata and the Atlantic Ocean; between –34º 07’ and –34º 55’ latitude and –58º 19’ and –54º04’ longitude. The closest continental land to the South of Montevideo is the Antartic (3200 km) and to the East is South Africa (6600 km); however, the influence of sea exposure on Uruguayan viticulture has not been studied. The aim of the current work was to assess the influence of this coastal environment on viticultural sites and, thus, solar radiation distribution was investigated due to its influence on the climate and plant physiology.

At the global scale, solar radiation generates atmospheric circulation, determines temperature, the hydrological cycle and the wind (Murphy and Hurtado, 2011). Correlations between climatic variables and those of vine functioning are the basis for individualizing the viticultural characteristics of a given region (Ferrer et al., 2007). Net radiation is the main component of the vine energy balance, promotes evaporation processes and plant transpiration (Carrasco and Ortega-Farias, 2008), it also determines dry matter production (Buttrose, 1969) and has a dominant effect over plant physiology acting through photosynthesis, thermal-response systems and phytochroma (Smart, 1989).

Reports by Makra et al. (2009), in the Tokaj region, indicated that amount and distribution of sun hours through the growing cycle affect to vintage yield and quality. In addition, Bois et al. (2008) carried out a study of the spatial and temporal variation of solar radiation in the viticultural region of Bordeaux, observing a West-East gradient of decreasing solar radiation; this allowed to identify three different zones according to the solar radiation level. In Uruguay, Abal et al (2011) mapped the spatial and temporal variation of solar irradiation, proving that the energy isolines showed a trend to get in line with winter parallels, rotating anti-clockwise till reach a Southwest-Northeast orientation in summer.

In the current article, the magnitude and distribution of incident solar radiation in six viticultural zones located in the left margin of the Río de la Plata were analyzed. The aim was to determine the existence of spatial differences, analyze their correlations with viticultural climate indices (Tonietto and Carbonneau, 2004) and generate elements that allow for an interpretation of the vintage effect on the 2011 to 2014 growing seasons.

2-Material and methods

The solar irradiation data were estimated by the Solar Energy Laboratory of the national public University (LES/UdelaR, http://les.edu.uy), and obtained using the BD-JPT statistical model (Alonso Suárez et al., 2012). The model is capable to generate solar irradiation data for any point in Uruguay's territory or surrounding areas for a given period of time, using only the set of GOES-East visible channel images. BD-JPT model is a modification of a pre-existing model (Justus et al., 1986; Tarpley et al., 1979) and greatly improves the performance of the original version. It was especially adjusted for the region using local ground measurements that were recorded in a few measurement's sites.

Average daily and monthly data for the period 2010 to 2014 and mean historical monthly values for period 2000 to 2014, were estimated for six locations (see Table 1) over the margins of the Río de la Plata, from September 01 to March 31 of each productive cycle. These locations were distributed over 266 km. Irradiation is given in MJ/m^2 for both daily and monthly values.

The correlations among climatic variables and mean daily irradiation, and those between viticultural climatic indices and cummulative irradiation were determined. Climate information was provided by meteorological stations that fulfill the WMO regulations: 2 were property of the Instituto de Investigaciones Agropecuarias (INIA), 3 were conventional stations and 2 pluviometric gauges from the Instituto Uruguayo de Meteorología (INUMET). In addition, 6 automated stations (Vantage Pro2, Davis Instruments, Hayward, CA, USA) were installed in the vineyards or their viccinities. The climatic variables registered were: maximum, minimum and mean air temperatures, rainfall, potential evapotranspiration, air relative humidity and heliophany. The viticultural climate indices Heliothermal (HI), Dryness (SI) and Cool Night Index (FI) were calculated according to the Geoviticulture MCC System (Tonietto and Carbonneau, 2004, adapted by Ferrer et al 2007). Cummulative growing degree-days (GDD10) were calculated up to harvest, according to Amerine and Winkler (1944). HI and SI indices were calculated from September 1st to the technological harvest date (HIh and SIh). Moreover, SI was also computed for February (ISf). Statistical analyses were carried out using INFOSTAT 2010 software.

3-Results and discussion

Irradiation and climate. Pearson correlation coefficients between mean daily irradiation and daily climatic variables (maximum and mean air temperature, cummulative rainfall, potential evapotranspiration, air relative humidity and heliophany) varied between 0.62 and 0.90, with p-values lesser than 0.0001 (Table 2). The significant correlation among variables was expected because of the known influence of irradiation on atmospheric processes (Murphy and Hurtado, 2011). Similarly, a high correlation between cummulative daily irradiation and viticultural indices, such as HI, GDD10 and ISf was observed; however, no correlation was found for SIh and FI. The lack of correlaton between irradiation and SIh could be explained by the different water holding capacity of the soils in the rootzone and also the rainfall distribution. The FI index reflects the lack of correlation between irradiation and minimum temperature, mainly because it is a night index.

Annual irradiation. For the period from 01/09 to 31/03 of the 2011 to 2014 growing cycles, mean daily irradiation showed a great variability between years, from 22.49 $MJ/m^2/day$ in 2012 to 20.59 $MJ/m^2/day$ in 2014, with a coefficient of variation (CV) greater than 20% in all the cases. The monthly mean daily irradiation of the four growing cycles reached its maximum in December with 27.42 $MJ/m^2/day$ and the higher variability in October (CV= 12.26%) and February (CV= 12.24%). February is the month during which ripening of ‘Tannat’ and other red cultivars occurs. The dynamics of monthly solar irradiation level for each vintage correlates with with vine growing kinetics and other plant response variables.

Irradiation as a function of location. The results of mean irradiation for each location presented a decreasing trend from West to East; although differences were not significant (α=0.05): Colonia 22.04 $MJ/m^2/day$, Sierra Mahoma 21.75 $MJ/m^2/day$, Punta Yeguas 21.83 $MJ/m^2/day$, Juanicó 21.62 $MJ/m^2/day$, Atlántida 21.58 $MJ/m^2/day$ and Sierra Ballena 21.14 $MJ/m^2/day$ (Figure N°1). For the period from 2000 to 2013, this trend was confirmed; however, the magnitude for each location was lower than that observed for the period from 2011 to 2014. These results are in agreement with those reported by Abal et al. (2011) and Bois et al. (2008), who also determined a West-East gradient.

The análisis of irradiation according to year and location reflected the same geographical trend; being the difference more evident on the geographic endpoints, although they are located at a similar latitude (-0º 21'). According to Buttrose (1969), Smart (1989) and Makra et al. (2009), differences on net irradiation should correlate with plant functioning. In this work, the differences in cummulative mean irradiation between the most distant locations would be equivalent, theoretically, either to a delay of 6-7 days in the growing cycle for a given cultivar, or, approximately, 0.4º-0.5º of probable alcoholic grade if harvest would take place on the same date for both locations.

It is likely that differences in heliophany caused by the effect of sea influence might be the cause of the reduction of incident energy on the East region of the coast.

According to the obtained results, solar irradiation showed differences along the coast of Río de la Plata, similarly to the results reported by Ferrer et al. (2007) for other climatic variables.

4-Conclusions

Solar irradiation was introduced as a basic element for viticultural zoning. The differences (trend) in incident energy observed, even for similar latitudes, might be used as a basis for vine growing site delimitation.

Measuring the evolution of this factor may allow the characterization of vintage and production zone. This could provide elements for the scientific interpretation of physiological processes that determine yield, fruit and wine composition as well as become a possible parameter which can help reasoning the cultural practices for a given region.

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6-Literature

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Table N° 1 Sites and geographical coordinates of studied areas

Tableau N°1 Sites et coordonnées géographiques des zones étudiées

Site - Department	Latitude S	Longitude W
Colonia del Sacramento - Colonia	34° 23'	57° 51'
Sierra Mahoma, San José	34° 07'	56° 56'
Punta Yeguas - Montevideo	34° 53'	56° 19'
Juanicó - Canelones	34° 37'	56° 15'
Atlántida – Canelones	34° 40'	55° 48'
Sierra Ballena - Maldonado	34° 44'	55° 01'

Table N°2 Pearson correlation coefficients between mean daily irradiance and daily weather variables and between radiation accumulated and viticultural climatic indices HIh, SIh, SIf, FI and GDD10, for the growing cycles 2011-2014

Tableau N°2 Pearson coefficients de corrélation entre l'irradiance moyenne quotidienne et les variables météorologiques quotidiennes et entre l'irradiation cumulative et les indices du climat viticole HIh, SIh, SIf, FI et GDD10, pour les cycles 2011-2014

Variables correlated with solar radiation	Pearson correlation coefficient	p Value
Maximum air temperature (◦C)	0.69	<0.0001
Mean air temperature (◦C)	0.62	<0.0001
Acumulated rainfall (mm)	0.83	<0.0001
Penman's potential evapotranspiration (mm)	0.90	<0.0001
Air relative humidity (%)	-0.63	<0.0001
Heliophany (hours)	0.84	<0.0001
Heliotermal index, 01/09 up to harvest : HIh(°C)	0.74	<0.0001
Dryness index of February:SIf (mm)	0.64	<0.0001
Dryness index, 01/09 up to harvest: SIh (mm)	**0.02**	**0.88**
Cool Night index: FI (◦C)	**-0.03**	**0.07**
GDD10 (◦C)	0.65	<0.0001

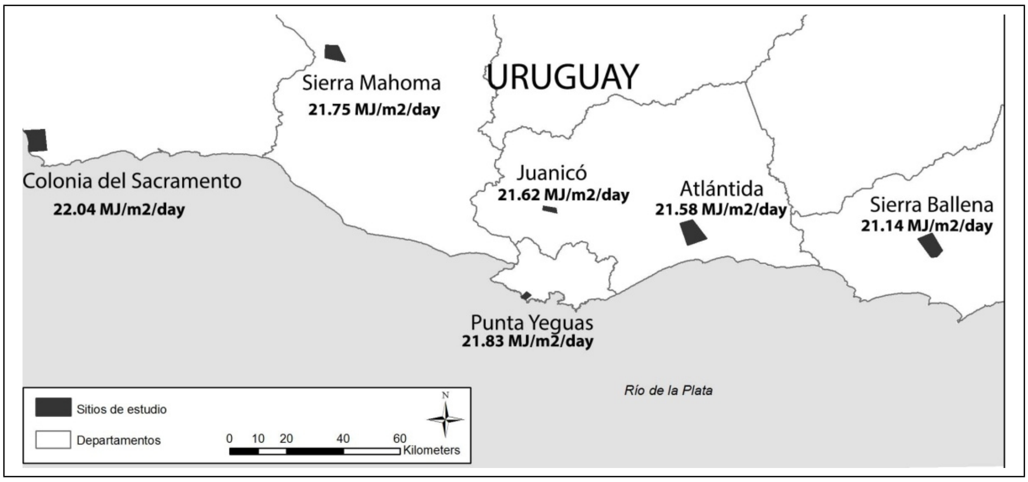

Figure N°1 Daily irradiance (mean) per zone, from 01/09 to 31/03. Years 2011 to 2014

Figure N°1 L'irradiance quotidienne (moyenne) par zone, à partir de 01/09 à 31/03.Ans 2011 à 2014