Italian Journal of Agrometeorology
Rivista Italiana di Agrometeorologia

Firenze University Press
www.fupress.com/ijam

OPEN ACCESS

Citation: G. Dal Monte, T. Labagnara, P. Cirigliano (2019) Agroclimatic evaluation of Val d'Agri (Basilicata, Italy) suitability for grapevine quality: the example of PDO "Terre dell'Alta Val d'Agri" area in a climate change scenario. *Italian Journal of Agrometeorology* (3): 3-12. doi: 10.13128/ijam-797

Received: December 18, 2017

Accepted: September 12, 2019

Published: December 28, 2019

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

Dal Monte G. and Labagnara T. contributed equally to this work.

Agroclimatic evaluation of Val d'Agri (Basilicata, Italy) suitability for grapevine quality: the example of PDO "Terre dell'Alta Val d'Agri" area in a climate change scenario

Studio agro-climatico della Val d'Agri (Basilicata, Italia) per la viticoltura di qualità: l'esempio della DOP "Terre dell'Alta Val d'Agri" nel contesto dei cambiamenti climatici

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Abstract. In a changing climate, the agro-climatic characteristics of a wine region could significantly vary. Therefore, grapevine physiology, ripening time and grape quality at harvest, could be modified by climate change. The aim of this work is to investigate if there is a shift in climate suitability for the PDO "Terre dell'Alta Val d'Agri" wine growing area. Firstly, the climatic traits were assessed for the reference period 1985-2010. Afterwards, according to a "two periods" approach, the 2010-2018 time period, that represents the current condition, was evaluated. The Multicriteria Climatic Classification (MCC) (Tonietto and Carbonneau, 2004), through the use of Heliothermal, Cold night and Dryness indexes, was performed and the classification of the two periods was compared in order to highlight the differences in the suitability for wine production in the PDO area. The results show the trend towards a warmer and drier climate, with an increase in mean temperature (+1°C) and intensification of dryness (+21 mm of potential deficit). The study also shows that, according to MCC, no relevant viticultural regions in the world are highlighted with the same classification as Villa d'Agri for the 1985-2010 period. Otherwise in the recent period (2011-2018) the study area has similar climatic traits with an important wine-producing area, the Rio Negro wine region in Argentina. This agro-climatic shift reveals a great potential in the suitability of the PDO area for high-quality red wine production. In addition, the "two periods approach" could be applied to other grape growing regions in order to assess the effect of climate change on vineyard suitability for wine production.

Keywords. Multicriteria climatic classification (MCC), bioclimatic index, grapevine suitability, PDO "Terre dell'Alta Val d'Agri", agro-climate change.

Riassunto. I cambiamenti climatici in atto possono influenzare in maniera significativa le caratteristiche di una regione viticola ed incidere, di conseguenza, sulla fisiologia della vite, sul periodo di maturazione e sulla qualità dell'uva alla raccolta. Scopo del presente lavoro è di evidenziare se nell'area della DOP "Terre dell'Alta Val d'Agri" si è verificato un cambiamento climatico che ha inciso sulla vocazione viticola del territorio. A questo fine sono state esaminate le caratteristiche del periodo climatico di riferimento 1985-2010; caratteristiche poi confrontate, secondo un approccio "a due periodi", con gli anni più recenti 2011-18. Successivamente l'area oggetto di studio è stata esaminata, separatamente per i due periodi, secondo il metodo della Classificazione Climatica Multicriterio (MCC) (Tonietto and Carbonneau, 2004), che utilizza gli indici Eliotermico, di Secchezza e di Freschezza notturna. I risultati mostrano una tendenza verso un clima più caldo e più secco, con un innalzamento della temperatura media di 1°C e con una riduzione dell'acqua disponibile. Quanto alla MCC, si evidenzia come i valori del periodo 1985-2010 non si riscontrino in altre zone viticole di rilievo a livello mondiale, mentre le caratteristiche riscontrate negli anni 2011-18 si ritrovano nella regione del Rio Negro, in Argentina. L'approccio "a due periodi" potrebbe essere applicato anche ad altre regioni viticole, per verificare gli effetti del cambiamento climatico sull'idoneità di un territorio alla produzione di uve per vini di qualità.

Parole chiave. Classificazione climatica multicriterio (MCC), indici Bioclimatici, adattamento della vite, DOP "Terre dell'Alta Val d'Agri", cambiamenti climatici.

INTRODUCTION

The influence of climate on grape and wine quality is well known (Montes *et al.,* 2012), through the effect of both regional and local-scale climatic conditions during the growing season, and by its inter-annual variability, which generates variations in grapevine growth and then in berry composition (Gladstones 1992, Jones and Davis 2000, Jones *et al.,* 2005, Soar *et al.*, 2008). Among climate variables, air temperature is recognized as having the greatest effect on grapevine and on biochemical changes in berries during their development and ripening (Jackson 2000, Carbonneau *et al.,* 2007), affecting plant vigor, ripening rate and harvest date (Jackson and Lombard, 1993). Temperature is also known to determine the concentration of aromatic and color compounds in berries under specific night time temperatures (Kliewer and Torres 1972, Kliewer 1973, Fregoni and Pezzutto 2000). Climate can also account for differences in wine quality and style (Matese *et al.*, 2014). The effects of climate on wine quality differences within a vine-growing region (at meso-climate scale) have been studied, *inter alia*, in Alsace (France) by Dumas *et al.* (1997), in Bordeaux (France) by Bois (2002), in Tuscany (Italy) by Bindi and Maselli (2001), in Veneto (Italy) by Tomasi *et al.* (2013) and in Oregon (USA) by Jones *et al.* (2004). So viticultural microclimatic and mesoclimatic characteristics, obviously joined with soil characteristics, are key factors in determining varietal suitability, wine types and wine quality of a wine region (Carbonneau, 2003; Jones 2006). Given the strong influence of climate factors on viticulture, it is also evident the importance to investigate climate change in progress and its impacts on grapevine growing areas. Furthermore, grapevine has a greater potential risk from climatic variations than other crops because, in general, optimum ripening conditions of a single variety occur only in a defined geographic zone (Jones *et al.*, 2005). Basilicata region includes four Protected Denomination of Origin (PDO) for a total red wine production more than 33.000 hL (Source: I numeri del vino su dati ISTAT-aggiornamento 2019.) In the area of Alta Val d'Agri that includes the territory of Viggiano, Moliterno and Grumento Nova municipalities (Fig. 1), in 2003 was established the PDO "Terre dell'Alta Val d'Agri" (Ministerial Decree, 2003). The official varieties cultivated in the PDO area are mainly red varieties such as Merlot, Cabernet Sauvignon and Malvasia di Basilicata, but it is allowed the utilization for a 20% of autochthonous minor or local red varieties. Concerning climate, there are no in-depth scientific studies about the peculiar characteristics of this territory. The area (about 25.000 hectares) is located at LAT 40° 21' 31" N, LON 15° 49' 30" E and consists of two landscape systems: the system of hill slopes, between 600 and 850 m a.s.l., and the valley system, between 550 and 650 m a.s.l. (Catizzone, 1980). Nevertheless, viticulture is widespread in a limited area, largely inside the environment of valley floor of Val d'Agri. The area of PDO, in which grapevine are cultivated, is about 215 hectare and spread around the valley of Agri river and its affluent. There are three main soil types in the PDO area: Inceptisol, that is the most widespread, Anfisol and Entisol (Cirigliano *et al.*, 2007). The climatic potentiality of the PDO "Terre dell'Alta Val d'Agri" was deeply investigated. With this fact in mind, the aims of the present study are: *i)* to describe the climate of the reference period (1985-2010) and characterize the recent one. (2010-2018); *ii)* to investigate consequences and perspectives of the climate change on thermal and hydric resources of the territory and *iii)* to evidence the possible effects of climate change on grapevine suitability.

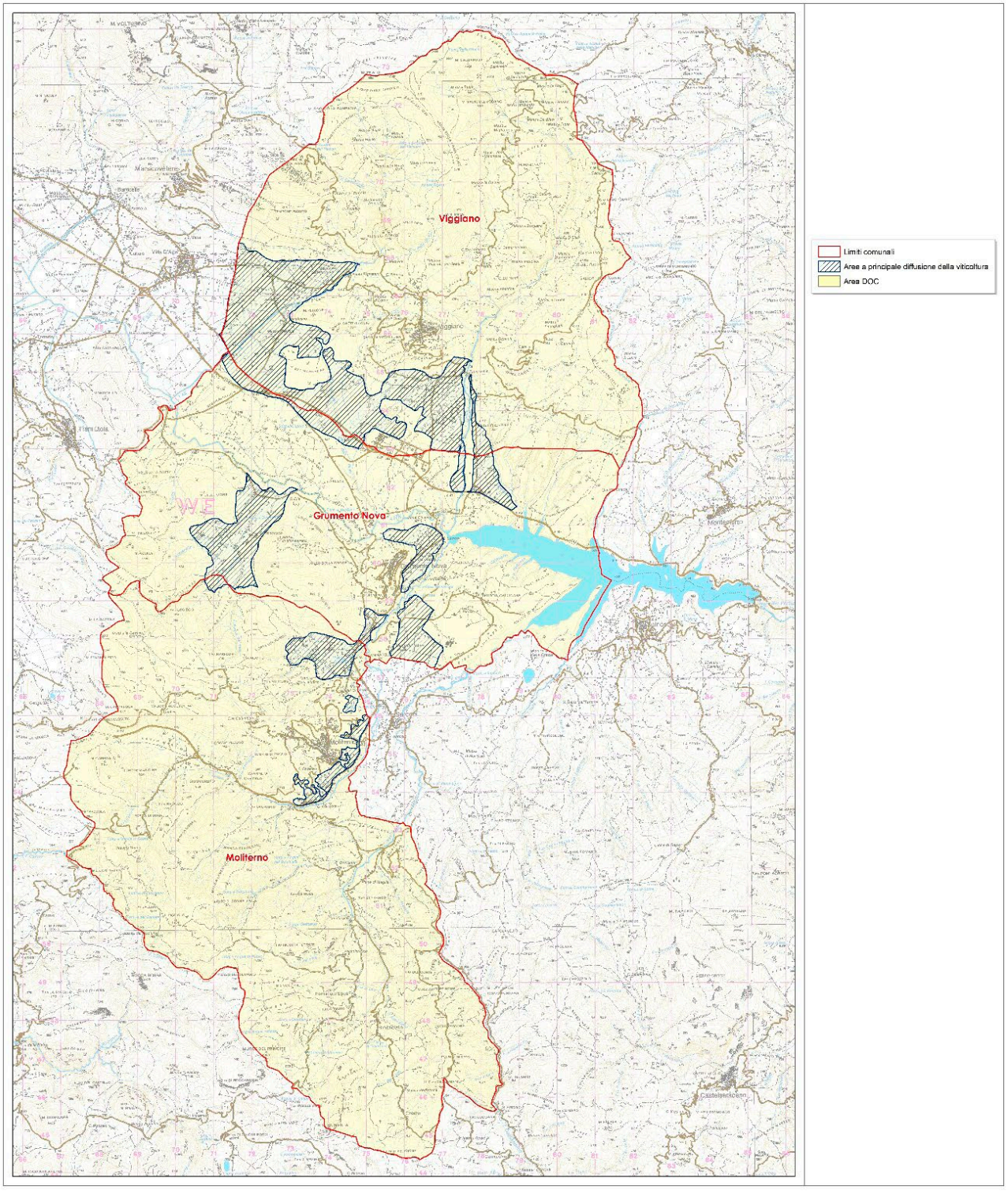

Fig. 1. The PDO "Terre dell'Alta Val d'Agri" area; it includes the territory of Viggiano, Moliterno and Grumento Nova municipalities.
Fig. 1. L'area della DOP "Terre dell'Alta Val d'Agri" che include i comuni di Viggiano, Moliterno e Grumento Nova.

MATERIALS AND METHODS

According to "OIV Guidelines for viticulture zoning methodologies on a climate level" (OIV, 2012), the best methodology to evaluate the agroclimatic features of a territory consists in three steps: the selection of appropriate climatic indicators, the evaluation of high qualitative climate data sources and the climatic identification of homogeneous zones. Since the purpose of this work is not to identify the homogeneous areas, but to better define the agro-climatic characteristics of the territory *a priori* defined as homogeneous, the research activity merely takes into account the first two steps and analyzes the achieved results.

Select climatic indicators

The multicriteria climatic classification (MCC system) proposed by Tonietto and Carbonneau (2004) was utilized in order to choose the most suitable climatic indicators. This system allows comparing the climate of the PDO area investigated with the main wine-growing areas in the world. According to the authors, the climate of a territory is strictly related to qualitative potential, grapes peculiarities or viticultural products (requirements of varieties, vintage quality, sugar, acidity, color, aroma) and the wine traits. Several studies evidenced the use of this climatic classification approach worldwide (e.g. Hormazabal *et al.*, 2002, Blanco-Ward *et al.*, 2007, Ferrer *et al.*, 2007, Jones *et al.*, 2009). Until now, no investigation was performed for the viticultural areas of Basilicata region, particularly for the PDO "Terre dell'Alta Val d'Agri". The present work, in addition to highlight the agroclimatic traits of the studied area and its suitability for grapevine cultivation, could also contribute to the validation of the classification system at the global scale. According to Tonietto and Carbonneau (2004), the best climatic indices (Tab. 1) to characterize the climate of grape-growing regions in terms of thermal and hydrological conditions are the Heliothermal index (HI), the Dryness index (DI) and the Cool night index (CI). The Heliothermal index allows assessing the thermal potential of a given region and links the thermal demands for variety ripening, reflecting the potential grape sugar content. The index estimates the suitability of a region to grow various grapevine varieties that depends on heat accumulations. Therefore, this index, using temperatures of the growing season (from April to September), give information about grapevine quality and varieties which can be cultivated in a certain area (Huglin, 1978). *Vitis vinifera* is highly sensitive to climate, temperature affect grape quality and production (Holland and Smit, 2014). Consequently, the amount of temperatures of growing seasons influences the entire grape and wine composition (Van Leeuwen and Destract-Irvine, 2017). HI represents

Tab. 1. List of bioclimatic indices used for climatic classification of PDO "Terre dell'Alta Val d' Agri", along with their corresponding definition and references.
Tab. 1. Lista degli indici bioclimatici per la classificazione della DOP "Terre dell'Alta Val d'Agri" e riferimenti bibliografici.

Bioclimatic index	Definition	Units	Reference
Heliotermal Index (HI)	$\sum_{April}^{September} \frac{[(T-10)+(Tx-10)]}{2} d$ T Mean Air Temperature (°C) Tx Maximum temperature (°C) d Length of day coefficient	°C	Huglin 1978
Dryness Index (DI)	$\sum_{April}^{September} (Wo + P - Tv - Es)$ *Wo* soil water reserve at the end of the growing season (mm) *P* Precipitation (mm) *Tv* = ETPk potential evapotranspiration in the vineyard (mm) (ETP = potential evapotranspiration, k = coefficient of radiation absorption by vineyard (in the Northern hemisphere: 0.1 for April 03 for May 0.5 from June to September)) *Es* effective evaporation from the soil (mm) (Es = ETP/N (1-k) JPm, where N = number of days in the month; JPm = number of days of effective evaporation from the soil per month, JPm = monthly rainfall in mm/5)	mm	Riou 1994
Cold night Index (CI)	Minimum air temperature of September	°C	Tonietto and Carbonneau 2004

a direct measurement of the impact of climate on viticulture and it is the most important index to evaluate the implications of global warming for viticulture worldwide (Marx *et al*., 2017). The Dryness index (DI)[1] (Riou, 1994) evaluates soil water availability for vine growing cycle, by estimating soil water reserves, precipitation and potential evapotranspiration (potential water balance). This is also a good indicator for grapevine development, as water availability it can influence yield and quality (Edwards and Clingeleffer 2013; Van Leeuwen *et al*., 2009; Roby *et al*., 2004) especially polyphenol accumulation (Cirigliano *et al*., 2017). The DI takes into account the vineyard potential evapotranspiration, the evaporation of bare soil and precipitation. The Cool Night Index (CI) accounts for minimum temperatures during the month before harvest (September, by convention, in the Northern emisphere) providing a gross estimate of the ripening stage, as large temperature ranges during ripening tend to be favorable to high-quality wines (Tonietto and Carbonneau, 2004). Furthermore, by combining these bioclimatic features of heat accumulation (HI), dryness (DI), and ripening conditions (CI), it is possible to determine the optimum viticulture suitability and direct comparison between different grapevine regions all over the world.

Select climate data source

The meteorological daily data (from 1985 to 2018) were collected in Villa d'Agri (PZ) station, located at LAT 40° 20' 58" N, LON 15° 49' 43" E, alt. 592 m a.s.l. This automatic station belongs to the agro-meteorological network of ALSIA (Agenzia Lucana per lo Sviluppo e l'Innovazione in Agricoltura). Reference evapotranspiration (ET_0) was estimated using the Hargreaves-Samani empirical equation (Hargreaves and Samani, 1982).

Climate change

In the last decades, several studies report techniques, methodologies and scenarios in order to evaluate trends and tendencies for future climate (Palliotti *et al*., 2014; Hannah *et al*., 2013; Fraga *et al*., 2016). In order to investigate if climate change is taking place in the studied area and if there are climatic trends that can affect, positively or negatively, the cultivation of grapevine and the quality and typicality of wines, the available meteorological data series were divided in two different subsets and were analyzed separately, according to a "two periods" approach: the first subset of twenty-five years 1985-2010 is sufficient to calculate climatological standard normal of the area (WMO, 2011); the second one takes into account the recent period of eight years (2011-2018), which describes the current situation and can give predictive information about the near future: "in general, the most recent 5- to 10-year period of record has as much predictive value as a 30-year record" (WMO, 2011). In addition, the above-mentioned bioclimatic indexes were calculated separately for the two datasets. Results were compared and discussed in the following sections.

RESULTS

Climatic traits of 1985-2010 vs. 2011-2018 periods

In Tab. 2 the differences between the two periods were highlighted. The mean annual temperature of the reference period (1985-2010) was 12.8°C instead of 13.8°C of the years 2011-18. For the reference period (1985-2010), the coldest month was January, with a mean temperature of 4.8°C and the warmest month was July with a mean temperature of 22.1°C. During the growing season (from April 1st to September 30th), the average total amount of precipitation was 284 mm and the corresponding value of evapotranspiration ETo was 927 mm, with a potential deficit of 642 mm. In the recent period (2011-2018), the coldest month was January again, but with a mean temperature of 5.4°C; the warmest month was August with a mean temperature of 23.1°C (Tab. 2). In addition, the average total amount of precipitation was 275 mm during the growing season and the corresponding value of evapotranspiration ETo was 971 mm, with a potential deficit of 663 mm.

Bioclimatic indexes and climate suitability 1985-2010 vs. 2011-2018

The climatic changes highlighted in the previous paragraph, could implicate a change in bioclimatic indexes and in climate suitability for grapevine of the study area. Table 3 evidenced the main results of agroclimatic classification for Villa d'Agri area. The value of HI is 2239 for the reference period (1985-2010) and it falls in the HI +1 class. According to Tonietto and Carbonneau (2004), the climate could be defined as "temperate warm", where the heliothermal resources are sufficient for the growth of almost all cultivars, even the later ones. However, the value of HI for the last eight-years (recent period) is higher (2436°C) because it

[1] In this work the Drought Index was calculated adopting Wo = 200 mm (Tonietto and Carbonneau, 2004)

Tab. 2. Climatic values of Villa d'Agri area for the periods 1985-2010 and 2011-2018.
Tab. 2. Valori climatici di Villa d'Agri per i periodi 1985-2010 e 2011-2018.

Period	Annual T mean	Coldest Month	Coldest Month T mean	Warmest Month	Warmest Month T mean	Mean Temperature*	Rain*	ETo*	Potential deficit*
1985-2010	12.8°C	January	4.8°C	July	22.1°C	17.7°C	284 mm	927 mm in July	642 mm
2011-2018	13.8°C	January	5.4°C	August	23.1°C	18.7°C	275 mm	971 mm in July	663 mm

Tab. 3. Results for Multicriteria classification system (MCC) of PDO "Terre dell'Alta Val d'Agri": heliothermal index, cool night index, dryness index and Classes of viticultural climate for the two periods are highlighted.
Tab. 3. Risultati relativi alla classificazione climatica multicriterio (MCC) della DOP "Terre dell'Alta Val d'Agri" sono riportati i valori degli indici eliotermico, di freschezza notturna e secchezza, per i periodi 1985-2010 e 2011-2018.

Index	1985-2010				2011-2018			
	Value	Class of viticultural climate	Acronym	Class interval	Value	Class of viticultural climate	Acronym	Class interval
Heliotermal Index, HI	2239	Temperate warm	HI+1	>2100 ≤ 2400	2436	Warm	HI+2	>2400 ≤ 3000
Cold Night index, CI (°C)	10.2	Very cool night	CI+2	≤12	10.4	Very cool night	CI +2	≤12
Dryness index, DI (mm)	-70	Moderately dry	DI+1	≤50 > −100	-177	Very dry	DI+2	≤−100

Tab. 4. Day-night thermal excursions of Villa d'Agri: 1985-2010 and 2011-2018 val ues.
Tab. 4. Escursioni termiche giornaliere di Villa d'Agri: confronto tra i valori 1985-2010 e 2011-2018.

Period	Mean*	Maximum monthly*	Absolute maximum*	Monthly mean* (August-September)
1985-2010	13.4°C	18.2°C August	27.4°C 7/7/2000; 10/9/2008	16.7°C
2011-2018	15.7°C	20.4°C July	29.1°C 18/9/2015	18.8°C

*Day-night thermal excursion.

reflects the rise in temperature of the last years, so the HI class is +2 "warm", where there is "a potential which exceeds the heliothermal needs to ripen the varieties, even the late ones (with some associated risks of stress)" (Tonietto and Carbonneau, 2004). (See also Figure 2 (a)). Concerning the CI index, there is only few differences between the values of the two periods (10.2 vs. 10.4) and both of them fall in the same class CI +2 "very cool nights", characterized by very low night temperature (for details see Figure 2 (b)). This index reflects the main specific climatic characteristic of the studied area: the very high values of diurnal temperature variation (see Tab. 4), particularly during berries ripening. The last index analyzed was the dryness index DI. Results highlighted a change in the value of the last eight years. In fact, in the reference period, the value is -70 and the class is DI+1 "moderately dry", so the climate was characterized by the presence of dryness. However, the value of DI in the recent period is -177 (with a high variation of more than 250% over the first period) and the class is +2 "very dry" (Tab. 3 and Fig. 2 (c)). Generally, this class represents areas with more than 100 mm of annual water deficit, where there are frequently water stress effects and vineyards irrigation are currently applied.

DISCUSSION

Climate change has strongly reached the attention of the scientific community concerning natural, social and political sciences. Furthermore, climate is one of the main factors that influence more the agricultural sector. Concerning the viticulture, scientists have deeply investigated the global implication of climate change on grapevine. Rise temperature is advancing maturity and compressing the harvest. Thermal regimes, seasonal condition, vine water status and the exploration of adaptation options for grapevine growers are key factors in order to evaluate the climate impact on yield, enologically important berry traits and viticulture suitabil-

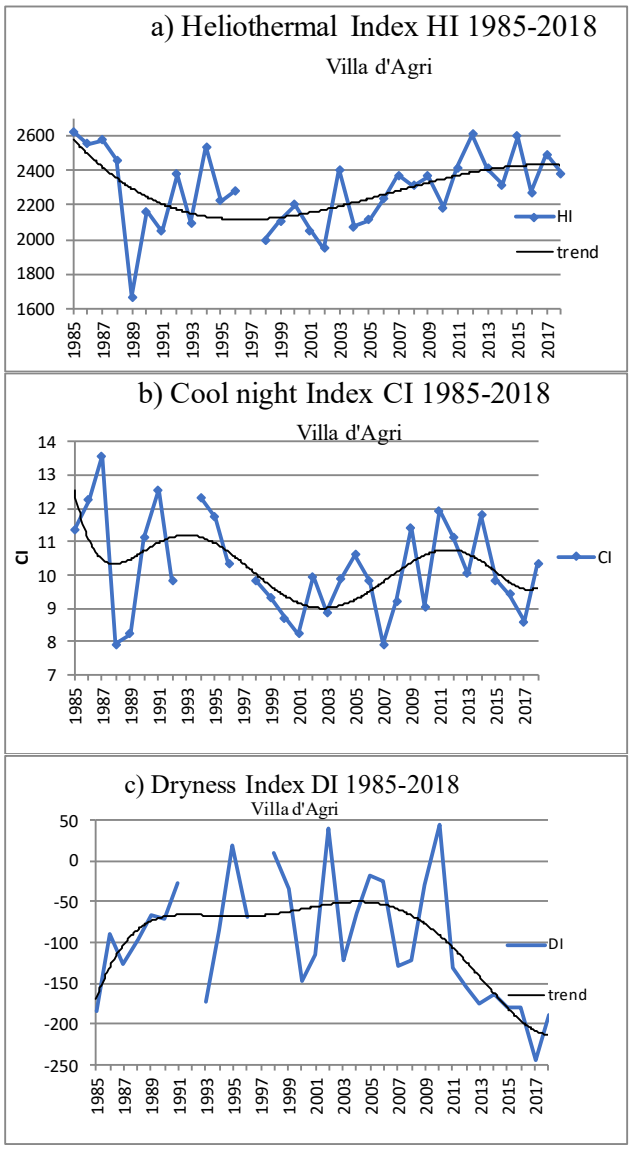

Fig. 2. Multicriteria climatic classification (MCC) of Villa d'Agri for the years 1985-2018; a) Heliotermal index (HI), b) Cold night index (CI) and c) Dryness index (D). The trend is shown by the continuous line.

Fig. 2. Classificazione climatica multicriterio (MCC) di Villa d'Agri per gli anni 1985-2018; a) Indice eliotermico (HI), b) Indice di Freschezza notturna (CI) e c) Indice di Secchezza. Il trend è evidenziato dalla linea continua.

ity. (Moran *et al.*, 2018; Marx *et al.*, 2017). However, few research groups have actually examined the implications and the consequences of the effect of climate change in small territories, mainly at regional scale (Zottele and Delay, 2017; Teslic *et al.*, 2017; Serpa *et al.*, 2017 and others). According to Multicriteria climatic classification system (MCC) (Tonietto and Carbonneau, 2004), the PDO "Terre dell'Alta Val d'Agri) was classified as "temperate warm", with "very cool nights" and "moderately dry" for the climatic period (1985-2010). Recently, according to climate change, the period between 2011-18 is classified, instead, as "warm", with "very cool nights" and "very dry", highlighting a clear trend towards rise temperatures and a less significant reduction in precipitation during the grapevine growing season. Therefore, some physiological problems could occur in zones with high heat accumulation, which could affect the aromatic potential of grapes not only in the earliest cultivars (Crespo *et al.*, 2017 and Pons *et al.*, 2017). However, in this area, rise in temperature is compensate for the very high day thermal excursions of the ripening period (Tab. 4) and the reduction of available water could be faced with rescue by irrigation. Nevertheless, both periods may fall into Gladstone's description of 'an ideal vineyard climate' (Gladstone's, 1992). The author reported that climate should be consistently warm, but not hot, days and cool nights throughout ripening, but particularly around the time of veraison to enhance maximal carbohydrate accumulation particularly for color formation. It is very interesting to note that in Tonietto and Carbonneau (2004), no important world viticultural regions were highlighted with the same classification as Villa d'Agri for the 1985-2010 period, indicating that no similar areas in the world corresponded to qualitative wine production. According to Jones *et al.*, (2005), the historical and estimated climate changes could move some regions into more optimal climatic conditions for the production of traditional grapevine varieties. Furthermore, climate change can enhance grape growing in some regions (Fraga *et al.*, 2012; Hannah *et al.*, 2013), this is the case for the small territory of Villa d'Agri in Basilicata, where climatic change could positively impact on grape growing. As a result of this study, in the recent period (2011-2018), the PDO "Terre dell'Alta Val d'Agri" wine-producing area highlights similar characteristics with another wine-producing region, according to the same Multicriteria classification categories (Tonietto and Carbonneau, 2004). In fact, in the 2011-2018 period (which has also a predictive value for the near future), Villa d'Agri falls in the same classification as Rio Negro wine region in Argentina, where (as in Villa d'Agri) night temperatures are very low. In the south area of Argentina (Patagonia), the Rio Negro province accounts for some 3% of total wine production of the country and the day-night temperature variations make a particular environment for the production of qualitative wine. In this contest, this desert climate produces arid growing conditions. Otherwise, the combination of warm, sunny days and very cold nights create an especially healthy environment for viticulture (Goldner and

Zamora, 2007). According to Kliewer and Torres (1972) night cooler temperatures increased anthocyanin concentration two to four times in comparison to grapevine grown under warmer conditions in Cardinal, Pinot noir and Tokay. Day-night thermal excursion has high positive effect on grape color and significantly affect the volatile content at grape maturity. (Alessandrini *et al.*, 2017). Consequently, the Rio Negro region is subject to a pronounced infra-day temperature variation, where warm days are followed by cold nights. This lengthens the growing season and leads to a balance of rich grape traits and acidity in the wines. Accordingly, Rio Negro is one of Argentina's up-and-coming wine regions and more grapevine producers are exploring its viticultural potential. The climate is cooler than in much of the rest of Argentina and "elegant, cool-climate styles of Pinot Noir, Sauvignon Blanc and Malbec are produced here" (Caballero, 2017). Due to these changes of temperatures and dryness conditions during 2011–2018, the PDO area become, from the agro-climatic point of view, more suitable for grapevine cultivation particularly for qualitative wines production. Basilicata region, from this perspective, is rich in term of grapevine biodiversity and it is part of the Third Centre of Domestication of *Vitis vinifera* (Del Lungo, 2016). Under this agro-climatic scenario, it could be suggested the selection of ancient autochthonous varieties that have been subjected to many natural selection cycles in thousands of years and have been crossed extreme climatic phases. For this reason, they have accumulated some genes, mainly still unexpressed, in their DNA, through the spontaneous intersection and mutation processes that allow them to give positive effect on yield and important grapevine properties in a climatic change condition (Labagnara *et al.*, 2018). Many authors investigated the potentialities of these ancient autochthonous varieties highlighting their peculiar traits (Labagnara *et al.*, 2018 and Alba *et al.*, 2016). In the PDO "Terre dell'Alta Val d'Agri", according to findings highlighted in this work, it could be suggested a future use of ancient varieties that could be suitable under these climate conditions. The ancient autochthonous varieties Aglianico B., Giosana B. and Santa Sofia (Alba *et al.*, 2016) are mainly proposed for their historical and cultural heritage of the PDO "Terre dell'Alta Val d'Agri".

CONCLUSIONS

The present study aimed to analyze the climatic potentiality and suitability of the area of the PDO "Terre dell'Alta Val d'Agri" according a "two periods" approach. The results confirm that the current climatic characteristics of the studied area are favorable for grapevine growth. In particular the day-night thermal excursion increased in the 2011-2018; consequently, it allows the increase of grape properties in terms of preserving a good level of sugar, freshness and aromatic complexity in berries. The global climate change is affecting the PDO "Terre dell'Alta Val d'Agri" with an increase in temperature and a small decrease in precipitation during the growing season. These changes evidence the agro-climatic similarity of PDO with the Rio Negro (Argentina) wine-growing region, highlighting new potentialities. These finding, in addition to the possibility to introduce the cultivation of ancient autochthonous late varieties or with greater thermal needs, could turn climate change into a threat to opportunities for the enhancement of Basilicata viticulture. The "two periods" approach can be applied to other grape growing regions in order to verify if climate change is modifying the suitability of the area for wine production.

ACKNOWLEDGMENTS

The authors thank dr. Emanuele Scalcione, of ALSIA, for supplying the weather data

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