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Research article

How Mediterranean winegrowers perceive climate change

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Abstract: Farmers are the most affected by the negative impacts of climate change and, at the same time, are called upon to adapt to climate change. Despite this, the degree of perception and adaptive attitude of farmers to climate change is still quite limited, especially in smallholder family farms in the Mediterranean areas. This study explores the level of perception of climate change by PDO (Protected Designation of Origin) winegrowers in a region of southern Italy (Sicily) and the adaptation actions able to cope with climate change, using a nonparametric approach. The analysis is based on data collected through self-administered questionnaires submitted to 380 PDO winegrowers. For variables comparison the Mann Whitney and the Kruskall Wallis test were applied according to the number of compared samples (two or more independent samples, respectively). Results show how winegrowers' perceptions of climate change tends to vary according to age and education of the respondents and to altitude and size of vineyards. This study highlights how information and dissemination of knowledge among winegrowers play a strategic role in the perception of climate change, especially in rural and remote Mediterranean areas.

Keywords: climate change; adaptation strategies; agriculture; winegrowers; perceptions; Mediterranean area

1. Introduction

To address climate change appropriately, consideration must be given to the understanding of agriculture-dependent rural communities of climate change and its risks. It is assumed that these communities have an innate, adaptive knowledge, also derived from their agricultural experience, from which to draw and survive in high-stress ecological and socio-economic conditions. Understanding their perception of climate change, the main climate risks, adaptation strategies and the factors influencing the choice of these strategies is essential to reduce farmers' vulnerability. Therefore, human responses, in terms of perception, are critical to understanding and estimating the effects of climate change on agricultural production and to facilitate adaptation. However, in rural communities, the link between agriculture and climate is overly complex. Farmers usually base their production decisions using a local knowledge system based on their agricultural experience. This provides families and farming communities with easier-to-follow climate forecast information, representing a significant cultural element for them [1]. The perception of climate change on which farmers base their decision making constitutes a process of adaptation to climate change [2]. Farmers will tend to take new measures in response to perceived climate change. Therefore, the information and technologies available will greatly influence their ability to adapt and react [3]. In this perspective, it becomes interesting to understand how the available information on climate change, climate variability and global warming can affect farmers' perceptions of climate change and the consequent adaptation measures [4]. On the other hand, since 2013, climate change has been among the main objectives of the Common Agricultural Policy (CAP). During 2014–2020, the European Commission assigned to climate change mitigation and adaptation actions more than a quarter of the total CAP budget. Furthermore, it has introduced actions aimed at promoting precision and conservation agriculture techniques through "no tillage" and greening measures to deal with greenhouse gas (GHG) emissions. In this perspective, also the CAP objective 4, in the new 2023–2027 programming, attributes to agriculture a key role in reducing GHG emissions through new soil management techniques. Adaptation measures refer to different levels: global, national, regional, or local. As stated by United Nations Framework Convention on Climate Change (UNFCCC) (2009), local level adaptation is the most crucial issue to face, since local actors are the ones that much more contribute to the severity of climate change. Generally, adaptation is a feature that could be separated in two stages. The former concerns the perception of climate change and the related risks; the other one is linked to the abatement of the adverse effects of climate change. In this perspective, perception should be improved, or otherwise the measures taken to reduce climate change (and related to inexact perceptions) could lead to undesirable consequences [5]. Hence, a proper perception depends both on the level of knowledge but also on levels of accessibility to information. Furthermore, although in many cases, amongst farming communities, climate change is well identified and adequately perceived, sometimes farmers are not able to face the effects of these changes due to limitations (including the lack of available information), to their beliefs or attitudes, or because they pay more attention to their economic performance rather than to the environmental maintenance. Accordingly, understanding the level of perception of climate change by farmers, the reliability and accuracy of the available information, becomes a fundamental issue, but it is equally important to understand how their perception stimulates adaptation measures. This may request changes in farming practices, types of cultivation, planting time or other farm management decisions. Lastly, farmers' awareness implies translating knowledge and information into agricultural choices, competencies, capabilities, behavior, and experience, but also into changes in rural outputs, harvests, revenue, food security or into other indicators able to improve farmers' livelihoods [6]. These actions influence farmers' perceptions but also the interactions between climatic and non-climatic factors [7].

This study is organized as follows. First, research gap and aim are presented in the section 2. Section 3 out the Research background of the study. General implications and contributions are illustrated in section 4. Next, the study area is presented. Consequently, in materials and methods section the sample is described, and the data analysis is developed. In the section 7 results, estimated using Mann Whitney and the Kruskall Wallis test, are presented. Finally, we present the discussion and conclusions derived from the results, the study's limitations, and some potential avenues for future investigation.

1.1. Research gap and aim

Soubry et al. [8] recognized that although the literature agrees that farmers' skills need to be integrated into the debate on land management and climate change adaptation, research integrating farmers' perceptions and practices as a contribution to adaptation is still marginal. In this perspective, this paper aims to explore the Mediterranean winegrowers' perceptions of climate change, focusing on Protected Designation of Origin (PDO) Sicilian winegrowers. It investigates the availability of information on climate change addressed to winegrowers, their possible translation in suitable and cost-effective adaptation measures in case of climate events affecting viticulture and winemaking sector (i.e., increasing trends in rainfall, erosivity, wind speed and rising temperature trends) and the perceptions of the causes of these events, also, based on their farming experience and on local conditions.

1.2. Research background: Farmers' perceptions of climate change

"Perception" and climate change represent crucial keywords to understand how farmers interpret climate change. In a study on farmers' perceptions of climate change, Elia [9] shows that although farmers were aware of change in climate and climate variability, they did not really understand climate change. On the other hand, as demonstrated by Soubry et al. [8] in a review on the topic, the term "perception" has rarely found a shared definition in the literature. Studies by Ayeri et al. [10] defined farmers' perceptions of climate change as assessments of climate variability and weather events occurred in a region over a certain time. Perceptions of climate change may vary according to the years of farming experience, education, economic conditions/resources (and thus rural livelihoods) age and gender [11]. Ribeiro et al. [12] include farming experience, geographical areas, and social attitudes/contexts, and Baul et al. [13] talk about "functional awareness" as a process of receiving and transforming environmental data. Other authors found that farmers' perceptions of climate change are linked to agricultural practices adopted in specific situations [14] and deriving from the local knowledge [15]. In this perspective, Mertz et al. [16] and Akponikpe et al. [17], found that information about climate change may be classified into two categories: (1) analysis and forecast supplied by academics, researchers, local governments, but also mass-media [18] and (2) local perceptions coming from indigenous knowledge transfer by family/friends and old generations. The Intergovernmental Panel on Climate Change (IPCC) defines indigenous knowledge as "the understandings [the knowledge] and skills developed by individuals and populations, specific to the places where they live" it is "a key element of the social and cultural systems which influence observations of, and responses to climate change" [19]. Accordingly, knowledge and perception are jointed aspects in the climate adaptation framework: while "knowledge" is equal to the sum of understanding, experience (past practices) and available information, "perception" is equal to the result of subjective judgements and reactions to determinate occurrences or actions (where climate events may constitute just an aspect). However, despite this range of definitions, knowledge and awareness of farmers can be considered crucial factors in understanding their "perception" of climate change. Consequently, the access to information, becomes a crucial point [20]. It was shown as farmers with a greater availability of information, tend to have a greater propensity to adopt innovative practices [21,22]. On the contrary, smallholder farmers (in developing countries), or farmers living in remote rural areas report significant problems in accessing to reliable and accurate information on climate change, also because of poor agricultural infrastructure [23]. To this research, farmers' perceptions of climate change have been defined as subjective assessments or belief based on the level of awareness and on the level of knowledge about the characteristics and severity of climate change and from which they derive the adoption of suitable actions to cope them [24]. This aspect favors agricultural adaptation practices [25] and could translate into the voluntary adoption of adaptation measures and spontaneous participation in programs focused on this topic [24]. To this end, all available instruments needed by farmers (prevalently smallholder farmers) to gather information and related to their agricultural activities are considered [26].

1.3. General implications and contributions for viticulture and wine production

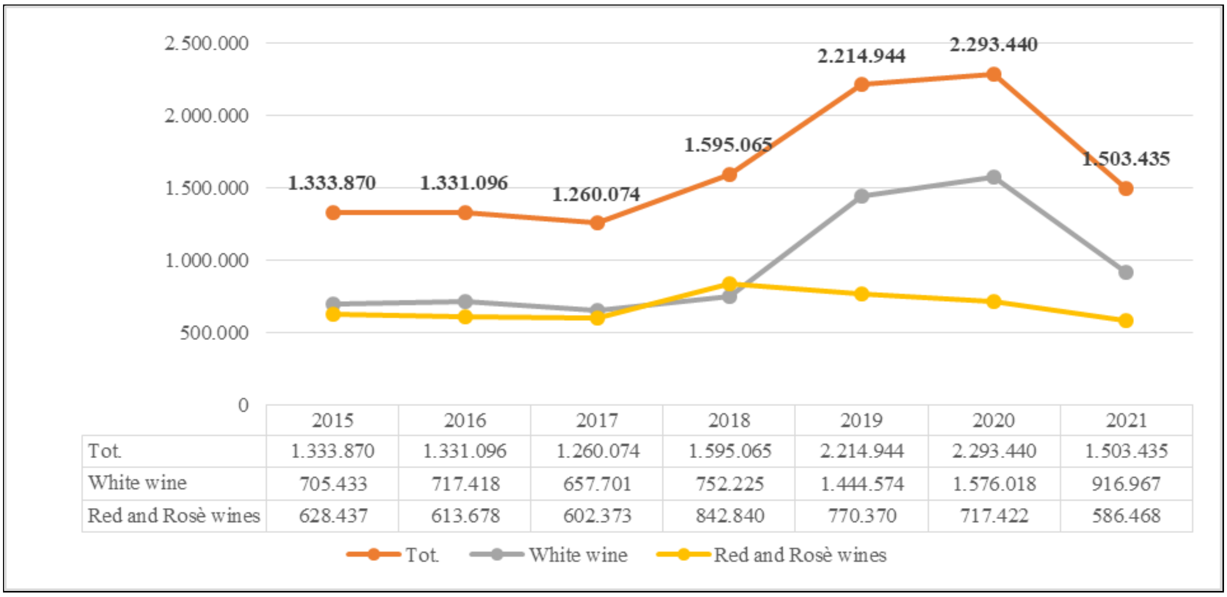
The agricultural sector is significantly subjected to climate change and consequently to its impacts. Climate change brings both positive and negative effects on local agricultural sustainability, where agricultural production affect food security, productivity, technology, and sustainability. Agriculture, in fact, is both vulnerable to climate change but also an important source of GHG emissions. Furthermore, climate change in the agricultural sector caused additional risks such as assets depletion (i.e., damage to the long-term sustainability of natural resources), price risks (i.e., risk of falling or rising prices), and financial risks (i.e., possible increase of interest rates, cost of capital, and investment decisions) [27]. Farmers who produce wine grapes, a crop particularly sensitive to climate change, are one of the agricultural actors most affected by the negative impacts of climate change. These risks can affect the productivity of vineyards, increase the volatility of prices, and compromise the profitability, inducing, in extreme cases, farmers to abandon their activities. This latter represents a concern for Italian agriculture and more specifically for the agriculture of the Mediterranean basin which is particularly affected by the climate change impacts [28]. In this perspective, to continue to obtain desirable results in the vineyard, winemakers have to consider and integrate not only a set of long-term (i.e., the life of the vineyard) and short-term (i.e., seasons) factors, but even exogenous factors such (climate) [29]. All these factors determine the yield of the vineyard, the attributes of grape and affect both the quality of the product (wine typicality), the profitability and sustainability of the vineyard and, consequently, the perception of the terroir of many traditional winegrowing regions [30].

1.4. Some effects of climate change on the viticulture sector in Mediterranean areas

In Mediterranean winegrowing regions, the climate has an important role in determining the microclimate of the frond, the growth, and composition of the grapes, which determine the characteristics, quality, and wine. Current climatic conditions, and the increase in global average temperature, have caused environmental changes in the Mediterranean terroir requiring serious adaptation and mitigation actions [31]. A study conducted by the *Centro Euro-Mediterraneo sui Cambiamenti Climatici* (CMCC) [32], in Italy, proves a general reduction in the duration of the vegetative stage of grapevine (characterized by an early ripening phase, especially in the Southern regions), a potential loss of agricultural vocation and productivity of several cultivation areas, and a possible their migration towards Northern areas. Furthermore, Santos et al. [30] highlight how Europe's southern regions will suffer the greatest losses of agricultural vocation due to drought, but also to very high temperatures that can cause quality losses associated with production processes (e.g., degradation organoleptic). In general terms, in the Europe's southern and Mediterranean regions, pronounced impacts can be expected both for arboreal and herbaceous crops. In these regions, the increase in temperature and water scarcity, can determine a greater variability in yields, a reduction in production of many crops, and consequent loss of their ability to produce typical and local products. These ecosystems are extremely expose to soil erosion due to soil poor nutrient content, high rainfall intensity, steep slopes, and scarce organic matter [33]. Furthermore, erosion risk in Mediterranean ecosystems affects land degradation and desertification processes [34,31]. In these areas, soil erosion derives also from land use and types of crops [35]. In Italy, the agricultural land destined for grape cultivation has increased by about 50,000 hectares in the last four years and it is still increasing. The destination of new areas for the cultivation of vines is one of the main reasons for soil erosion, because the more recent vineyards are responsible for a higher rate of soil erosion than the existing ones. Many vineyards in Mediterranean regions are located on slopes, which exacerbates the potential risk of erosion. In particular, the vineyards cultivated on hilly zones record higher soil erosion rates than other types of cultivation as cereals, olive groves, etc. [36]. The consequences of erosion affect grapevines because eroded soils are characterized by low fertility and reduced water retention capacity. In general, the severity of soil erosion rates in vineyards is linked both to the characteristics and management of the soil, to climate models, and to water storage losses due to tillage operations. Accordingly, the Europe's southern and Mediterranean winegrowing regions could risk losing in its viticultural vocation due to high temperatures and increasing drought and may not guarantee a winemaking [37–39]. Effects that have affected especially the conventionally managed vineyards [40,41]. In addition, changes in temperatures and humidity may rise the presence of parasites and parasite-borne diseases [42]. According to Gristina et al. [43] in Sicily, more than 50,000 ha of vineyards are in sloping hillslopes. The soil erosion in these territories is very high both for rainfall dynamics -the study area is characterized by MST1 climatic region (Mediterranean to subtropical), influenced by mountains— which presents relatively higher annual precipitation and lower potential evapotranspiration rates, see Fantappiè et al. [44] -and for soil organic matter degradation caused by land tillage. Consequently, the awareness, perceptions, or the knowledge of climate change could help to improve adaptation practices or to increase the resilience of those territories. Several studies [45–48] show, for example, that using some herbaceous species as cover crops, may protect the soil surface from the impact of rainfall, limiting soil erosion and enhances the ground quality (i.e., improving soil humus reservoirs). These experimental practices, based on cover vegetation management operations, have been applied in limited areas in Sicily and have been shown some benefits during the winter season, when vineyards are inactive. Consequently, the role of information and awareness in the winegrowers' perceptions of climate change become an important issue to address future adaptation challenges, avoid environmental and economic losses and to improve soil management and conservation.

1.5. Study area

In Sicily, according to the Italian National Statistical Institute (Istat) [49], the production of PDO wine in 2021, represented a 7.6% share of the total Italian production of PDO wine (equal to 19,774,572 hectoliters), with a decrease of 0.34% compared to 2020. These data derive from 24 designations of PDO origin (which expects that a wine assure clear quality standards and be produced in a definite region), that is 6% of the total of Italian PDO wines (409 PDO national designations). Furthermore, this market segment can be considered as a central economic and agricultural sector for the development of the local economy because it collects 59% of the entire wine production in Sicily, showing, over time, a potential capacity to growth, as shown in Figure 1.



	2015	2016	2017	2018	2019	2020	2021
Tot.	1.333.870	1.331.096	1.260.074	1.595.065	2.214.944	2.293.440	1.503.435
White wine	705.433	717.418	657.701	752.225	1.444.574	1.576.018	916.967
Red and Rosè wines	628.437	613.678	602.373	842.840	770.370	717.422	586.468

Figure 1. Total PDO wine production in hectolitres in Sicily by years (2015–2021). Source: authors elaboration on the base of ISTAT data (2021).

In particular, in 2021, the total production of PDO wine in Sicily amounted to 1,503.435 hectoliters, showing a decrease in production compared to the trend of the previous years, probably attributed to the economic condition due to the pandemic period. This trend replicates the same data for white wine production, in particular the data show −42% for PDO white wine production respect to the data of 2020, and −18% attributable to PDO red and rosé wine production confirming the same trend of 2019, in which the decrease was equal to −7% compared to the previos year.

The total area destined for the cultivation of PDO grapes in Sicily is equal to 47,118 hectares [49]. This area mainly covers the hilly zones (in particular it varies from hilly areas to areas of undulating and flat land), with the exception of the eastern area of the island, mainly mountainous, dominated by the Etna Volcano, as shown in Figure 2.

The climate is Mediterranean (hot dry summers and mild winters, or alpine in the hinterland and at higher altitudes), rainfall is scarce along the southern coasts and in the neighboring hinterland where additional irrigation is required. The configuration of vineyards is uneven and limited in size due to the large fragmentation of the property and in which the vineyard management method is still the traditional one.

N°	PDO wines in Sicily	Type of wine	% of the total regional production (hl)-(year 2018)
1	Cerasuolo di Vittoria	R	0.4
2	Alcamo	R; W; RS; S	1.0
3	Contea di Sclafani	R; W	0.1
4	Contessa Entellina	R; W; RS	0.1
5	Delia Nivolelli	R; W; S	0.0
6	Eloro	R; RS	0.1
7	Erice	R; W; S	0.1
8	Etna	R; W; RS	2.9
9	Faro	R	0.0
10	Malvasia delle Lipari	W	0.0
11	Mamertino di Milazzo	R; W	0.1
12	Marsala	R; W	3.7
13	Menfi	R; W; S	0.8
14	Monreale	R; W; RS	0.1
15	Noto	R; W; S	0.3
16	Pantelleria	W; S	0.6
17	Riesi	R; W; RS; S	0.0
18	Salaparuta	R; W	0.2
19	Sambuca di Sicilia	R; W; RS	0.0
20	Santa Margherita di Belice	R; W	0.0
21	Sciacca	R; W; RS	0.0
22	Sicilia*	R; W; RS; S	89.1
23	Siracusa	R; W; S	0.0
24	Vittoria	R; W	0.3

Figure 2. Distibuction of PDO wine production in Sicily (* All areas). Type of wine: R: red wine; W: white wine; RS: rose wine; S: sparkling wine.

2. Materials and methods

2.1. Data Collection

A survey methodology based on a questionnaire self-administered was used to collect the data, according to Battaglini et al. [50] who analyzed the perception and impact of climate change among winemakers in France, Germany, and Italy. To this aim, the PDO winegrowers' awareness based on knowledge transfer process was measured through 380 questionnaires, distributed between September and December 2022.

The sample was chosen based on the data provided by the database of the *Registro delle Imprese* (Registroimprese.it) held by the local Chamber of Commerce. The *Registro delle Imprese* is, a register containing complete information on all firms (of any legal form and economic sector) located in the provincial territory. This made it possible to identify a complete list of SMEs (n. 1,015) located, under the heading "viticulture", in the study area. The profile of winegrowers was screened in order to retrieve contact details and determine their actual inclusion in the final list. The result was eight hundred e-mail addresses. The questionnaire was emailed to the owner of each farm, asking for complete it only if the production was certified as PDO. After several reminders, a total of 380 questionnaires were received.

The questionnaire was designed to collect information related to perception on climate change, capacities of winegrowers to cope with climate change and to connect the sources of information-awareness with the actions. The questionnaire covered the following sections:

Socio-demographic profile of the winegrowers, to obtain information on winegrowers' socio-demographic data such as location of vineyard; gender; age; education status and years (continuous) of experience in farming.

Farm/Vineyard characteristics. This section collected information about vineyard management and organization in terms of labor; vineyard size (ha) and altitude.

Winegrowers' perceptions on climate change. For obtaining data related to the winegrowers'' perception on these climate variables: (a) frequency of droughts; (b) inundating; (c) rainfall models and temperature; (c) impact on soil, and changes in land use; (d) concerns about insect pests, diseases, and weeds on crops; (e) water resource management.

Access to information. According to Abegunde et al. [51] winegrowers can obtain information on climate change from various sources, they generally prefer searching, receiving, and transmitting information that could be beneficial to the productivity of the vineyard. In this perspective, the aim of this section was to collect data on the level of importance that winegrowers attribute to the different sources from which they derive information on climate change, in details: (a) local government; (b) sector organizations active in agriculture; (c) information booklets; (d) specialized books; (e) newspapers and magazines; (f) the Internet; (g) television/radio; (h) education; (i) family and friends.

Winegrowers' knowledge about climate change. This section was used to obtain information about winegrowers' capabilities to adapt to climate change. 9 practices were selected on the basis of climate literature -see for instance Kemausuor et al.[52]; Hasibuan et al.[53]; Singh [54], -and are linked to the level of knowledge about the adaptation measures/actions adopted for the protection of the vineyard by: (a) increasing temperatures, (b) increasing dry season period; (c) severe storms; (d) increasing rainy season period; (e) increase in floods; (f) frequency and wind intensity; (g) farming risks such as pest and market price fluctuations; (h) vulnerability of farming activities to climatic factors; (i) management strategies to adapt to climate and weather related risks (i.e. changing planting dates, diversifying from farm to non-farm activities, increasing the use of irrigation, moving to different sites).

Subjective evaluation of the causes of climate change in the wine-growing sector. This section, based on farming experience, was used to obtain information about the evaluation of the causes of climate change. It aims to evaluate the reasons for events that occurred in the past on the basis of the adopted practices and available information, in particular: (a) negligence; (b) random event; (c) human activities and population growth; (d) deforestation; (e) animal breeding and feed production; (f) use of nitrogen fertilizers (e.g., nitrogen is the mineral that most affects the growth of the grapevine); (g) economic expediency; (h) absence of regulations/controls.

To test variables a five-point rating scale was used.

2.2. Data Analysis

From a descriptive point of view, categorical variables (gender, age classes, etc.) were expressed as absolute frequencies and percentages. We calculated mean ± standard deviation (SD) of the scores, attributed by each respondent to all variables detected within the four macro areas [55]. The nonparametric approach was used since all variables have an ordinal nature with five possible evaluation items [56–58]. We performed the statistical comparison between age classes (≤45 vs >45 years), between the educational status of the respondents (diploma vs degree) and, also, between the altitude position of the vineyard (plain vs hill/mountain) using the Mann Whitney test; the comparison between the size of the vineyard (<5 ha, between 5 and 10 ha and >10 ha) was performed with the Kruskall Wallis test. As regards the gender of the respondents and the company name, no comparison was made due to the lack of balance between the sample sizes. For statistical analysis, SPSS statistical package (version 22) was used. A p-value lower than 0.050 was considered to be statistically significant.

3. Results and discussion

For this study, 380 winegrowers (70% males and 30% females) were selected. 55% of respondents are over 45 years old. The majority of interviewed are highly educated with more than half of them holding a high school degree (55% of the sample) and a third a university degree (45% of the sample). As for vineyard surface, 152 respondents hold a vineyard with a surface less than 5 hectares, and 152 winegrowers have a vineyard with an area between 5 and 10 hectares, while only 76 respondents (20% of the sample) have a vineyard with an area exceeding 10 hectares. As for altimetric position, 228 winemakers (60% of the sample) declare that their vineyard is in the plains, while the rest of the respondents (40%) in a hilly/mountainous area. Lastly, 75% of respondents manage the company as an individual form and only 25% as a partnership. In the supplementary Table A.1 we reported the absolute frequencies and percentages of categorical variables, referred to the respondents (gender, age classes and educational status) and to the vineyard (size, altitude position and business name). Tables 1–4 show the mean values and standard deviation of the scores attributed to all investigated factors and the p-value of the different comparisons.

On the bases of the obtained results some significant relationships are highlighted.

The comparisons between age groups (Table 1) show that subjects belonging to "over 45" class not only give greater importance to the information on climate change, provided by associations and/or industrial organizations ($p = 0.006$), but also attribute a significant impact on climatic variations towards factors such as negligence ($p = 0.036$), randomness ($p = 0.024$), anthropogenic activities ($p = 0.003$) and development of livestock farms ($p = 0.002$).

For all other items, age does not seem to represent a discriminating element on the assessments of the investigated factors.

For the educational status (Table 2) we found only a significance in relation to the sources of information: for this macro-area, in fact, graduates give greater importance to information brochures (p = 0.013). The same graduates, as regards the actions to be taken to stem the climate changes, show a significantly greater knowledge regarding the adaptation measures that refer to the increase on the dry season period (p = 0.005), the cloudburst increase (p = 0.014) and increased rainy season period (p = 0.014). Finally, they attribute a significant impact on climate change using nitrogen fertilizers (p = 0.001).

Table 1. Mean values ±SD of the scores attributed to all investigated factors and p-value of the comparisons between age classes of the respondent.

CLIMATE VARIABLES	≤45 years	>45 years	P-value
Drought	4.00 ± 0.50	4.27 ± 0.47	0.228
Flooding	2.78 ± 1.09	3.45 ± 1.04	0.133
Temperature	3.89 ± 0.78	4.09 ± 0.30	0.424
Climatic conditions on the ground	3.22 ± 1.09	3.82 ± 0.75	0.201
Pests, diseases, and weeds	3.78 ± 0.97	3.64 ± 1.21	0.783
Water resource management	3.78 ± 0.83	3.91 ± 0.83	0.715
SOURCES OF INFORMATION RELATING TO CLIMATE CHANGE			
Local administration	2.22 ± 0.83	2.44 ± 1.24	0.852
Industry organization/association	2.67 ± 0.71	3.91 ± 0.94	0.006
Information brochures	2.00 ± 0.71	2.50 ± 1.08	0.282
Internet	3.33 ± 1.32	3.10 ± 1.10	0.697
Specialized books	3.11 ± 0.33	3.90 ± 0.99	0.062
Newspapers and magazines	2.67 ± 1.00	2.90 ± 1.10	0.655
TV and radio	2.33 ± 1.00	2.50 ± 0.97	0.667
Educational level	4.33 ± 1.00	4.60 ± 0.52	0.708
Family, friends, and acquaintances	2.33 ± 1.00	2.50 ± 1.18	0.702
KNOWLEDGE ACTIONS TO BE TAKEN TO ARGINE THE CONSEQUENCES OF CLIMATE CHANGE			
Temperature increase	2.89 ± 0.78	3.09 ± 0.83	0.572
Increase in the dry season period	3.00 ± 0.71	3.00 ± 0.89	0.979
Cloudburst increase	2.67 ± 0.50	3.18 ± 0.98	0.184
Increased rainy season period	2.44 ± 0.53	3.36 ± 0.81	0.014
Rising floods	2.78 ± 0.83	2.91 ± 0.94	0.775
Increased wind intensity	2.89 ± 0.78	3.36 ± 0.81	0.181
Agricultural risks	3.67 ± 1.32	3.36 ± 0.81	0.582
Water resource management	3.11 ± 0.93	3.27 ± 0.90	0.679
Management strategies	3.56 ± 1.42	3.64 ± 1.29	0.936
EVALUATION OF THE IMPACT OF CAUSES ON CLIMATE CHANGE			
Negligence	3.44 ± 0.53	4.27 ± 0.90	0.036
Randomness	2.56 ± 0.53	3.36 ± 0.81	0.024
Anthropic activities	2.78 ± 0.44	3.73 ± 0.65	0.003
Forest felling	4.11 ± 0.60	4.55 ± 0.52	0.110
Development of livestock farms	3.11 ± 0.78	4.18 ± 0.40	0.002
Use of nitrogen fertilizers	3.78 ± 0.83	3.82 ± 0.75	0.870
Economic opportunities	2.89 ± 1.45	3.82 ± 0.75	0.153
Absence of regulations/controls	3.89 ± 1.16	4.54 ± 0.52	0.193

Table 2. Mean values ±SD of the scores attributed to all investigated factors and p-value of the comparisons between the educational status of respondents.

CLIMATE VARIABLES	Diploma	Degree	P-value
Drought	4.09 ± 0.30	4.22 ± 0.67	0.482
Flooding	2.91 ± 1.22	3.44 ± 0.88	0.178
Temperature	4.09 ± 0.30	3.89 ± 0.78	0.424
Climatic conditions on the ground	3.55 ± 1.04	3.56 ± 0.88	0.971
Pests, diseases, and weeds	3.73 ± 1.35	3.67 ± 0.71	0.813
Water resource management	3.55 ± 0.69	4.22 ± 0.83	0.068
SOURCES OF INFORMATION RELATING TO CLIMATE CHANGE			
Local administration	2.40 ± 0.84	2.25 ± 1.28	0.398
Industry organization/ association	3.36 ± 0.67	3.33 ± 1.41	0.863
Information brochures	1.80 ± 0.92	2.78 ± 0.67	0.013
Internet	3.10 ± 1.20	3.33 ± 1.22	0.634
Specialized books	3.20 ± 0.63	3.89 ± 0.93	0.062
Newspapers and magazines	2.40 ± 0.70	3.22 ± 1.20	0.090
TV and radio	2.30 ± 0.82	2.56 ± 1.13	0.576
Educational level	4.60 ± 0.52	4.33 ± 1.00	0.708
Family, friends, and acquaintances	2.30 ± 1.34	2.56 ± 0.73	0.610
KNOWLEDGE ACTIONS TO BE TAKEN TO ARGINE THE CONSEQUENCES OF CLIMATE CHANGE			
Temperature increase	2.73 ± 0.65	3.33 ± 0.87	0.090
Increase in the dry season period	2.55 ± 0.69	3.56 ± 0.53	0.005
Cloudburst increase	2.55 ± 0.82	3.44 ± 0.53	0.014
Increased rainy season period	2.55 ± 0.82	3.44 ± 0.53	0.014
Rising floods	2.73 ± 0.90	3.00 ± 0.87	0.463
Increased wind intensity	3.09 ± 0.94	3.22 ± 0.67	0.808
Agricultural risks	3.27 ± 1.19	3.78 ± 0.83	0.306
Water resource management	3.09 ± 0.94	3.33 ± 0.87	0.562
Management strategies	3.45 ± 1.37	3.78 ± 1.30	0.576
EVALUATION OF THE IMPACT OF CAUSES ON CLIMATE CHANGE			
Negligence	4.00 ± 0.77	3.78 ± 0.97	0.518
Randomness	2.91 ± 0.83	3.11 ± 0.78	0.572
Anthropic activities	3.27 ± 0.47	3.33 ± 1.00	0.866
Forest felling	4.45 ± 0.52	4.22 ± 0.67	0.436
Development of livestock farms	3.55 ± 0.82	3.89 ± 0.78	0.490
Use of nitrogen fertilizers	3.27 ± 0.47	4.44 ± 0.53	0.001
Economic opportunities	3.09 ± 1.14	3.78 ± 1.20	0.177
Absence of regulations / controls	4.45 ± 0.52	4.00 ± 1.22	0.585

Table 3. Mean values ±SD of the scores attributed to all investigated factors and p-value of the comparisons between size of vineyard.

CLIMATE VARIABLES	<5 ha	5–10 ha	>10 ha	P-value
Drought	4.13 ± 0.64	4.25 ± 0.46	4.00 ± 0.02	0.683
Flooding	3.12 ± 0.99	3.50 ± 1.31	2.50 ± 0.58	0.383
Temperature	4.00 ± 0.76	4.00 ± 0.53	4.00 ± 0.02	0.987
Climatic conditions on the ground	2.88 ± 0.83	4.25 ± 0.71	3.50 ± 0.58	0.015
Pests, diseases, and weeds	3.25 ± 0.71	4.25 ± 0.89	3.50 ± 1.73	0.162
Water resource management	4.13 ± 0.83	3.75 ± 0.89	3.50 ± 0.58	0.424
SOURCES OF INFORMATION RELATING TO CLIMATE CHANGE				
Local administration	2.14 ± 0.69	2.71 ± 1.25	2.00 ± 1.15	0.570
Industry organization/association	2.81 ± 0.35	3.75 ± 1.49	3.50 ± 0.58	0.142
Information brochures	2.88 ± 0.83	2.00 ± 0.82	1.50 ± 0.58	0.037
Internet	2.86 ± 1.25	3.71 ± 1.11	3.00 ± 1.15	0.331
Specialized books	3.75 ± 0.89	3.57 ± 0.98	3.00 ± 0.00	0.281
Newspapers and magazines	3.63 ± 1.06	2.29 ± 0.49	2.00 ± 0.00	0.006
TV and radio	2.38 ± 1.06	2.71 ± 0.76	2.00 ± 1.15	0.447
Educational level	4.38 ± 1.06	4.57 ± 0.53	4.50 ± 0.58	0.974
Family, friends, and acquaintances	2.50 ± 0.53	2.29 ± 1.25	2.50 ± 1.73	0.937
KNOWLEDGE ACTIONS TO BE TAKEN TO ARGINE THE CONSEQUENCES OF CLIMATE CHANGE				
Temperature increase	2.88 ± 0.64	3.38 ± 0.92	2.50 ± 0.58	0.168
Increase in the dry season period	3.13 ± 0.35	3.38 ± 0.92	2.00 ± 0.00	0.016
Cloudburst increase	3.25 ± 0.46	3.13 ± 0.99	2.00 ± 0.00	0.032
Increased rainy season period	3.00 ± 0.76	3.13 ± 0.99	2.50 ± 0.58	0.468
Rising floods	2.88 ± 0.83	3.25 ± 0.89	2.00 ± 0.00	0.060
Increased wind intensity	3.13 ± 0.64	3.25 ± 0.89	3.00 ± 1.15	0.880
Agricultural risks	3.75 ± 1.04	3.50 ± 1.07	3.00 ± 1.15	0.583
Water resource management	3.13 ± 0.83	3.38 ± 0.92	3.00 ± 1.15	0.746
Management strategies	3.50 ± 1.31	3.75 ± 1.28	3.50 ± 1.73	0.946
EVALUATION OF THE IMPACT OF CAUSES ON CLIMATE CHANGE				
Negligence	3.13 ± 0.35	4.38 ± 0.74	4.50 ± 0.58	0.003
Randomness	2.88 ± 0.35	3.13 ± 0.99	3.00 ± 1.15	0.820
Anthropic activities	3.38 ± 0.92	3.13 ± 0.64	3.50 ± 0.58	0.650
Forest felling	3.87 ± 0.35	4.75 ± 0.46	4.50 ± 0.58	0.009
Development of livestock farms	3.25 ± 0.89	4.00 ± 0.76	4.00 ± 0.00	0.156
Use of nitrogen fertilizers	3.88 ± 0.64	4.13 ± 0.83	3.00 ± 0.00	0.044
Economic opportunities	3.13 ± 1.55	3.63 ± 1.06	3.50 ± 0.58	0.903
Absence of regulations/controls	4.13 ± 0.99	4.25 ± 1.04	4.50 ± 0.58	0.839

Table 4. Mean values ±SD of the scores attributed to all investigated factors and p-value of the comparisons between altitude position of the vineyard.

CLIMATE VARIABLES	Plain	Hill/Mountain	P-value
Drought	3.92 ± 0.29	4.50 ± 0.53	0.008
Flooding	2.75 ± 1.06	3.75 ± 0.89	0.030
Temperature	4.00 ± 0.43	4.00 ± 0.76	0.958
Climatic conditions on the ground	3.42 ± 1.00	3.75 ± 0.89	0.570
Pests, diseases, and weeds	3.67 ± 1.07	3.75 ± 1.16	0.810
Water resource management	3.42 ± 0.67	4.50 ± 0.53	0.003
SOURCES OF INFORMATION RELATING TO CLIMATE CHANGE			
Local administration	2.64 ± 0.50	1.86 ± 1.46	0.025
Industry organization/association	3.33 ± 0.78	3.38 ± 1.41	0.726
Information brochures	2.25 ± 1.14	2.29 ± 0.49	0.824
Internet	3.33 ± 1.15	3.00 ± 1.29	0.531
Specialized books	3.67 ± 0.98	3.29 ± 0.49	0.536
Newspapers and magazines	2.75 ± 0.75	2.86 ± 1.46	0.611
TV and radio	2.58 ± 0.51	2.14 ± 1.46	0.397
Educational level	4.42 ± 0.90	4.57 ± 0.53	0.923
Family, friends, and acquaintances	2.25 ± 1.06	2.71 ± 1.11	0.379
KNOWLEDGE ACTIONS TO BE TAKEN TO ARGINE THE CONSEQUENCES OF CLIMATE CHANGE			
Temperature increase	2.83 ± 0.72	3.25 ± 0.89	0.251
Increase in the dry season period	2.83 ± 0.72	3.25 ± 0.89	0.251
Cloudburst increase	2.92 ± 0.90	3.00 ± 0.76	0.806
Increased rainy season period	2.75 ± 0.97	3.25 ± 0.46	0.160
Rising floods	2.92 ± 0.90	2.75 ± 0.89	0.679
Increased wind intensity	2.92 ± 0.90	3.50 ± 0.53	0.139
Agricultural risks	3.17 ± 1.11	4.00 ± 0.76	0.079
Water resource management	3.00 ± 0.85	3.50 ± 0.93	0.179
Management strategies	3.33 ± 1.30	4.00 ± 1.31	0.330
EVALUATION OF THE IMPACT OF CAUSES ON CLIMATE CHANGE			
Negligence	3.83 ± 0.72	4.00 ± 1.07	0.743
Randomness	2.83 ± 0.72	3.25 ± 0.89	0.251
Anthropic activities	3.33 ± 0.49	3.25 ± 1.04	0.731
Forest felling	4.42 ± 0.67	4.25 ± 0.46	0.429
Development of livestock farms	3.67 ± 0.98	3.75 ± 0.46	0.998
Use of nitrogen fertilizers	3.67 ± 0.78	4.00 ± 0.76	0.320
Economic opportunities	3.67 ± 1.37	3.00 ± 0.76	0.076
Absence of regulations/controls	4.42 ± 0.51	4.00 ± 1.31	0.798

Table 3 refers to the comparison between three groups of farms, distinguished by size. Analyzing the macro-areas of variables, we can find several significances. First, with reference to climatic variations, we note that the smaller vineyards (<5 ha) compared to the larger ones (5–10 ha and >10 ha) perceive that the climatic conditions on the ground ($p = 0.015$) have a little impact on their sector, causing only small changes on the carried-out activity (average score 2.88). Also, in relation to "sources of information relating to climate change" we found that small vineyards determine the significance of comparisons for some items; in particular, they give greater importance, compared to larger ones, to the information provided by brochures ($p = 0.037$), newspapers and magazines ($p = 0.006$). As regards to "knowledge actions to be taken to contain the consequences of climate change" macro-area, the largest vineyards (>10 ha) distinguished from the others by the lack of knowledge, denoted by lower average scores, which they express in reference to "increase in the dry season period" ($p = 0.016$) and "cloudburst increase" ($p = 0.032$). In reference to "evaluation of the impact of causes on climate change" macro-area, the medium-large companies give great importance to some factors as negligence ($p = 0.003$) and forest felling ($p = 0.009$); however, referring to "use of nitrogen fertilizers", the medium-sized vineyard attribute greater weight (average score equal to 4.13) to this cause of climate change ($p = 0.044$).

The application of the Mann-Whitney test to groups of vineyards, distinguished according to their altitude position (Table 4), provided some significance in correspondence with climatic variations and the sources of information relating to them. Specifically, the vineyards located in the hills/mountains consider drought ($p = 0.008$), flooding ($p = 0.030$) and water resource management ($p = 0.003$) as factors that have caused great changes.

The only significance that we found at "Sources of information on climate change" shows that those who manage a vineyard located in plains prefer to use local administration as a source ($p = 0.025$). For all other items, there is no significance, and this denotes a similar behavior between vineyards, whatever the altitude at which they are located.

4. Conclusions

This research focused on the PDO winegrowers' perceptions of climate change in a region of Southern Italy (Sicily). As regard the methodology of this research PDO winegrowers' perceptions of climate change, were assessed based on the sources of available information obtained also according to farming experience. The results of this study help to strengthen what has been demonstrated in the literature in particular by: Hartter et al. [11]; Ribeiro et al. [12] and Baul et al. [13]. Particularly, the study confirms as perception is influenced and shaped, among other things, by the individuals' characteristics, their experience, the information that they receive, education, and the cultural and geographic context in which they live. In addition, the study confirms that perceptions based on an adequate information context led to greater adaptation intentions than perceptions based on limited or even absent knowledge.

In this perspective, some interesting aspects derived from the different groups of aggregation used to test variables (macro-areas). These groups made it possible to verify both the variables considered by the respondents as the most closely linked to climate change, and to understand how the responses varied according to the characteristics of the macro-area considered. In details, the macro-area corresponding to the age classes of respondents, reveals thar the respondents "over 45" not only give greater importance to the information on climate change, provided by agricultural organizations (i.e. cooperatives), but also they considered both negligence, randomness, anthropogenic activities, and the growth of livestock farms in order to response to the increased food demand of livestock products as factors that are increasingly influencing global climate change. While the former is associated with the sources utilized by winegrowers to access to information, the latest are linked to the subjective evaluation of the causes of climate change in the agricultural sector and it depend on farming experience, as demonstrated also by Ribeiro et al. [12]. In addition, as regard the assessment of winegrowers' adaptation to climate change based on the level of knowledge, "graduates" show a significantly greater knowledge regarding the adaptation measures. They are aware that the use of nitrogen fertilizers contributes significantly to the overall impact of agriculture on climate change and prefer to verify the accuracy of the available information. These results confirm as stated by Chérif et al. [14] and Gamble et al. [15] who have shown that the perception of climate change is a complex process that includes several aspects such as knowledge, beliefs, attitudes, and concerns about whether and how the climate is changing. Consequently, as stated by Birthal et al., [20] the availability of information represents a crucial point, because a person's perception of climate change can be influenced or modified by the information received and retained. Furthermore, the comparison among three groups of winegrowers, by size, shows several significances. First, smaller vineyards (<5 ha) than larger ones (5–10 ha and >10 ha) perceive that land use changes have little impact on vineyard cultivation, causing only small variations in harvest. Also, in relation to "sources of information relating to climate change", small vineyards give greater importance to the information provided by brochures, newspapers, and magazines, consistent with what demonstrated by Asare-Nuamah and Botchway [18]. As regards to "actions to be taken to face climate change" the largest vineyards (>10 ha) cite "lack of information/understanding" as an enabling factor to prevent the "increase in the dry season period" and "increase of severe storms". These results demonstrate that adaptation measures not only require winegrowers to perceive that the climate is changing or could change, but also to give adequate weight to this perception of change, in order to "be willing" to act on it., as stated by Eakin et al. [59]. In this sense, perceiving that the climate is changing can be considered as a pre-condition for the adoption of agricultural adaptation measures. In conclusion, this study does not reveal a common vision on the perception of climate change by winegrowers, in the study area. It disclosed that the most used sources of information are brochures, newspapers and magazines, no relevance is attributed to the Internet, personal knowledge (also acquired through farming experience) or information from family and friends. Similar results are found regarding information on adaptation and mitigation actions to reduce GHG emissions, the data show how the responses tend to vary according to age, level of education, or altitude, and size of vineyards. This result is in line with Hartter at al. (2012).

4.1. Practical and managerial implications

Protecting Mediterranean farmers, directly dependent on viticulture, from the negative effects of climate change through adaptation measures is a key aspect. Under conditions of perfect information, the decision to take or implement a particular adaptation measure would simply be a matter of weighing up the benefits and costs of that measure. However, this is certainly not the context in which small winegrowers (in the Mediterranean area, particularly) operate. Therefore, taking adaptation measures is not an automatic or effortless process. This research has shown that factors such as: limited access to information, but also to insurance or credit, inadequacy in the adoption of technologies, limited knowledge of climate change and adaptation measures, constitute barriers that small winegrowers have to face in order to adapt their production to climate change. Furthermore, the decision to adopt a new technology or a more environmentally friendly production method often involves cognitive processes, such as personal knowledge, beliefs, attitudes, and concerns about climate and, firstly, how the climate is changing, which can lead to levels of suboptimal adoption. This is particularly relevant for climate change adaptation, as even winegrowers with access to climate information face significant levels of uncertainty.

In conclusion, the result of this study highlights how information and the dissemination of knowledge among winegrowers play a strategic role in the perception of climate change, especially in rural and remote areas. Therefore, this research represents a contribution for local governance which will have to implement suitable measures to encourage investment in research, and in the attainment of new knowledge, through the active participation of all stakeholders (farmers/winegrowers, policy makers, researchers, consumers) involved in the agri-food supply chains “from field to fork”. If this participation is carried out in a profitable way, the results could produce suggestions and proposals for the design of adaptation policies that are more appropriate to local conditions, more efficient, less expensive and which encourage rural development. It is essential that winegrowers are well informed about the effects of climate change and possible adaptation strategies, as well as the best practices available for climate change mitigation, in order to adopt sustainable agricultural and vineyard management practices. This is important because a non-real perception of climate change can lead to the risk that winegrowers adopt inadequate management strategies or to the abandonment of those areas most exposed to climate instability with the risk of exacerbating desertification.

4.2. Limitations and future research

While this study provides insights on the PDO winegrowers’ perceptions of climate change, it suffers of several limitations. First, the sample represents a specific area of production in the Southern Italy for this reason is very specific, future developments could envisage an expansion of the research to obtain results that are more extendable to the reference sector. Furthermore, the data are related to a single period, while the climate change is not a static phenomenon, future research could explore these results over time. At the same time, the study recommends intensification of climate education, climate change awareness, guidelines, and action programs for sustainable development at local level to spread and increase awareness of this topic. Under these conditions, studying the perception and adaptation to climate change by Mediterranean DPO winegrowers could represent a very promising future research agenda from a purely academic perspective, but, above all, could be very relevant to provide valuable information that they could help in the design and proper implementation of public policies.

Supplementary

Table A.1. Absolute frequencies and percentages of categorical variables.

VARIABLES		N.	%
Gender	Male	266	70%
	Female	114	30%
Age classes	>45 years	171	45%
	>45 years	209	55%
Educational status	Diploma	209	55%
	Degree	171	45%
Size of Vineyard	<5 ha	152	40%
	5–10 ha	152	40%
	>10 ha	76	20%
Altitude position	Plain	228	60%
	Hill/mountain	152	40%
Business name	Individual	285	75%
	Partnership	95	25%

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