BAE
Bio-based and Applied Economics

AIEAA
ASSOCIAZIONE ITALIANA DI ECONOMIA AGRARIA E APPLICATA

OPEN ACCESS

Citation: Pagliacci, F., & Salpina, D. (2024). Adapting to climate change: what really drives the choices of the producers of Geographical Indications?. *Bio-based and Applied Economics* 13(3): 265-283. doi: 10.36253/bae-15221

Received: October 2, 2023
Accepted: April 9, 2024
Published: October 16, 2024

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.

Editor: Valentina Raimondi, Luca Salvatici

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Adapting to climate change: what really drives the choices of the producers of Geographical Indications?

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Abstract. In an era of rapid climate change, there is an increasing call for the efforts directed at detecting best practices of climate change adaptation in agriculture and understanding the factors behind producers' willingness to implement adaptation strategies. Many studies consider solely traditional agriculture and specific sectors (e.g., wine), while little attention has been paid to certified and high-quality products, as a whole. To fill this knowledge gap, in 2022 a questionnaire-based online survey was administered to 137 producers of agri-food Geographical Indications in the Veneto Region (north-eastern Italy). Using a multinomial logit model, this study highlights the factors explaining adaptation strategies distinguishing three cases: (i) farmers who have implemented adaptation strategies; (ii) farmers intending to implement them in the future; (iii) farmers neither having implemented nor willing to do so. Results suggest that socio-demographic characteristics, particularly education, matter, with producers holding a high school degree in agriculture showing a greater willingness to adapt. Also, being full-time farmer couples with higher probability of having already implemented adaptation strategies. Lastly, also a direct observation of climate change in the production area affects farmers' adaptation decisions.

Keywords: climate change, adaptation, PDOs, PGIs, producers' survey.
JEL Codes: Q1, Q15, Q54.

1. INTRODUCTION

One of the major recommendations of the United Nations Climate Change Conference COP27 (in 2022) is the recognition of the importance of sharing best adaptation practices among public and private key stakeholders, while adjusting them to country-specific context (UNFCCC, 2022). In such a setting, national governments have the direct responsibility of detecting best practices, highlighting the main factors behind climate change adaptation.

For the agri-food sector, both incremental and transformational climate change adaptation strategies have a paramount importance (Howden et al.,

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2010; Ingram, 2012; Fedele et al., 2019). Although incremental adaptation strategies alone are commonly considered insufficient to achieve the zero-hunger target of Sustainable Development Goal 2 (SDG2) and address the impacts of climate change (FAO, 2018), they can indeed contribute to national and regional transformative adaptation processes, especially in the case of local level strategies (Rahman et al., 2021).

However, adaptation to climate change for agri-food geographical indication (GI) systems is even more complex process, due to the legislative and institutional framework characterising them. Indeed, for each GI, a Product Specification (hereinafter, PS) defines the delimited area of production as well as production rules (e.g., plant varieties, harvest dates, size and colour). According to the World Trade Organisation (WTO, 1994), GIs are indications aimed at identifying goods as produced in a given geographical area, whose quality and reputation are attributable to the geographical origin itself. In practice, GIs are considered as a sort of social constructions (Belletti et al., 2017), which play a crucial role in fostering endogenous rural development, hence contributing to the preservation of the traditional agri-food systems and related social networks (Vandecandelaere et al., 2010), and thus, to socio-economic and environmental sustainability of the concerned rural areas (Owen et al., 2020). However, to contribute to this goal, GI management must be implemented effectively (Giacomini and Mancini, 2015) and GI regulations put producers under obligation to comply with the respective PS. The complex policy and socio-economic processes on which GIs rely on (Thompson and Scoones, 2009) often makes the modification of their PS complex, even if for the urgent purpose of climate change adaptation. In particular, the introduction of such changes requires an agreement among the involved producers, which can be concerned with long and costly authorisation processes (Belletti et al., 2015; Quiñones-Ruiz et al., 2018) on the one hand, and with the product's quality and reputation at stake, on the other hand. All these reasons explain why agri-food GIs are quite vulnerable to climate change.

In this setting, GIs adaptation to climate change depends on the capacity of agents and institutions to innovate, hence finding new solutions. Information on already-existing adaptation practices and a better understanding of the drivers behind the willingness of GI agents to adapt is crucial in informing public policies. Indeed, policies can foster anticipatory adaptation strategies within the agri-food sector. This is particularly important when self-investment for adaptation is insufficient, also due to the existence of major financial constraints, both in high-income and low-income countries (Ignaciuk, 2015; Deressa et al., 2009).

For the last decade, the studies addressing climate change adaptation of farmers have increased, especially in low-income countries. They have focused either on specific territories, e.g., the "char" islands in Bangladesh (Ahmed et al., 2021), the Amazon basin (Bauer et al., 2022), Laikipia District in Kenya (Ogalleh et al., 2012); or on specific productions, such as tea (Muench et al., 2021), coffee (Bro, 2020), honey (Vercelli, et al. 2021). In fact, only a few studies focused on the nexus of climate change adaptation and GIs in high-income countries. According to Marescotti et al. (2020), safeguarding Protected Designations of Origins (PDOs) and Protected Geographical Indications (PGIs) from the effects of climate change is a rather new topic mostly disregarded by international literature. Some studies addressed climate change perception of wine producers (e.g., Lereboullet, 2013; Lamonaca et al., 2021), while there is paucity of studies focusing on agri-food GIs, specifically. To this regard, a recent study by Henry (2023) suggested the chance for agricultural supply relocation as an option to adapt to climate change, even in the case of GI labels. Although this chance is currently excluded outside of the boundaries of the designed geographical area of production, it is still true that – at least in principle - changes in the geographical area of production are admitted as non-minor amendments by Regulation (EU) No 1151/2012 (Article 53). However, according to an analysis of the amendments in the fruit and vegetable sector in the EU by Marescotti et al. (2020), only one out of 81 non-minor amendments until 2018 affected the area of production, justifying the need to enlarge the production area with climate change. Actually, Henry (2023) also stressed the existence of expected negative impact on quality of products, limiting similar relocations.

This research aims to shed new light on local adaptation strategies in the case of agri-food GIs in the Veneto Region (north-eastern Italy), i.e., one of the regions with the highest climate change risk in Italy (ARPAV, 2017). In particular, its objective is to highlight the main factors influencing the decision of producers to counter climate change impact. The main research questions of this study are: What are the main adaptation practices used by producers of agri-food GIs? And what are the main factors influencing the willingness of agri-food GI producers to adapt?

In order to answer these questions, the study is based on a structured online survey, targeted to agri-food GI producers in the case-study area. With the help of primary data, it highlights the main adaptation practices in place as well as the factors influencing the willingness of farmers to implement them (either currently or in the future). Adaptation revolves around the complex interplay of socio-demographic characteristics (e.g., age, education), management characteristics and networking activity, production type, altitude as well as climate change perception itself. To estimate these factors, a multinomial logit model is used. Findings suggest that despite a generalised awareness of climate change, this has not yet turned into widespread decision to implement adaptation measures. Rather, developing peer-to-peer learning practices among farmers and fostering collaborations among those GI systems that face similar risks is of utmost importance.

The paper is structured as follows. Section 2 provides the theoretical background on adaptation to climate change and on the factors affecting adaptation. Section 3 discusses the materials and methods used, by briefly describing the case study area, the sample, data collection and analysis. Section 4 presents the results of the study, while Section 5 discusses them. Section 6 explores the main policy implications of this study and Section 7 concludes.

2. THEORETICAL BACKGROUND: FACTORS OF CLIMATE CHANGE ADAPTATION

Within climate change literature, adaptation is defined as a process of adjustment to current or future climate and its effects, so as to reduce harm or take advantage of some positive opportunities (IPCC, 2014). In agriculture, there are many climate change adaptation measures (e.g., technological and behavioural, reactive and anticipatory; tactical and strategical) (Ingram, 2012). Adaptation options can be grouped into the following categories: cultivars and breed improvements; changing management practices; switching crops, breeds and farming systems; managing water; diversifying agricultural systems; managing fisheries and supply chain options (FAO, 2018). However, in the case of GIs, adaptation is somehow hindered by the PSs, given that they define bounded production areas and well-codified production rules (Thompson and Scoones, 2009). For example, many GIs include the specifications on crop varieties and breeds (Salpina and Pagliacci, 2022a), hence adaptation requires a modification of the code of practices, turning into long and costly authorisation processes (Belletti et al., 2015; Quiñones-Ruiz et al., 2018). However, despite the extensive literature on GI products, just a few studies provide insights into PSs amendments justified by climate change (e.g., Marescotti et al., 2020; Belletti et al., 2015). Thus, according to Marescotti et al. (2020), compliance with the PSs might be more difficult to attain due to climate change, which would limit adaptation options.

Overall, scholars distinguish between two types of adaptation processes (i.e., incremental and transformational), based on the expected complexity of their implementation, their costs, expected risks, and the number and heterogeneity of the different stakeholders who are engaged (Howden et al., 2010). Incremental adaptation refers to short-term measures implemented at local level based on farmers' knowledge and experience (e.g., introduction of rain covers). Transformational adaptation refers to long-term measures implemented at a larger spatial scale (region, state), suitable when impact intensity is high (e.g., changes in the boundaries of the production area). FAO (2007) also distinguishes between 1) autonomous or on-farm adaptation, i.e., the reaction of a single farmer to climate change; and 2) planned adaptation, as policy options or response strategies, which modify adaptive capacity or ease the introduction of given adaptation strategies. Being GIs "social constructions" (Belletti et al., 2017), both types of adaptation matter, involving both single producers and broader managing authorities. In particular, the understanding of both incremental (autonomous) and transformational (planned) methods of adaptation is crucial for the agri-food sector (Ingram, 2012; Fedele et al., 2019). The transformational or planned adaptation is usually influenced by the socio-economic and political structure of a given country or region. However, at farm level, the factors behind climate change adaptation can vary considerably.

In the case of GIs, these factors can be grouped into four areas: socio-demographic characteristics of producers, farm management and networks; product characteristics; climate change magnitude and its perception.

Socio-demographic characteristics. Studies on climate change adaptation usually claim that a number of socio-demographic variables influence the development and the transmission of innovations at the farm level, including age (Morel and Cartau, 2023), sex (Zamasiya et al., 2017) and education level (Guo et al. 2021). These factors affect the absorptive capacity of farmers towards innovations and the introduction of new agricultural practices, including adaptation to climate change, making easier the acquisition, assimilation, use, and transformation of external knowledge in the decision making process (Asrat and Simane, 2018; Abdala et al., 2022).

Farm management and networks. Besides socio-demographic characteristics of producers, other characteristics of the farm management matter, as well as the networks in which a farm is involved (Below et al. 2012; Khan et al., 2020; Gao et al., 2022). With regard to management practices, the difference between part-time and full-time farmers is important. Although declining in Europe (Shahzad and Fischer, 2022), part-time farming is still present, hence affecting the decisions about climate change adaptation. Full-time farmers are more likely to have more information and knowledge on changes in climatic conditions than part-time farmers, hence the former being more prone to adaptation (Maponya and Mpandeli, 2012). This can also be associated with less time dedicated to farm-related activities by a part-time farmer. Also, the presence of formal and informal networks as a part of social capital (Akahoshi & Binotto, 2016), within and outside each single GI system, can explain diffusion of innovation, hence encouraging agri-food GI producers to innovate (Wang et al., 2021). According to Ingram & Kirwan (2011), informal relationships can facilitate the formation of joint ventures for information exchange and business partnerships, and thus accelerate the adaptation in agriculture.

Product characteristics. Adaptation to climate change can be also affected by some characteristics related to the type of production as well as regulatory issues. Firstly, the effects of climate change – hence, the adaptation practices – differ considerably among, e.g., crop-based or animal-based productions (FAO, 2018). Secondly, and in the case of GIs, type of the certification (i.e., either a PDO or a PGI) may influence adaptation to climate change. Actually, the restrictions imposed by each denomination, particularly in terms of size of production area, provenance of raw materials and production processes, are different, with the former being tighter than the latter.

Magnitude and perception of climate change. When addressing climate change-related risks, several studies have claimed that adaptation decisions can depend both on the (measurable) magnitude of climate change and on individual perceptions. Therefore, in the context of adapting to climate change at the farm level, the effectiveness of adaptation measures can depend both on the overall increase of temperature and on farmers' ability to perceive climate-related hazards, evaluating their impact on production. According to many theories aimed at explaining the risk-reducing behaviour of economic agents against natural hazards, different perception of climate change can emphasise subjective aspect in assessing the risks associated with it. For instance, according to the Protection Motivation Theory (PMT), rooted in the theory of planned behaviour (Fishbein and Ajzen, 1975; Grothmann and Reusswig, 2006), individuals' decisions to engage in a protective response against natural hazards are driven, among others, by threat appraisal (also known as 'risk perception'), which encompasses perceived probability and perceived consequences that an individual associates with a certain hazard (Fishbein and Ajzen, 2010; Fahad et al., 2020; Ahmed et al. 2021; Talanow et al., 2021). Similarly, in the case of climate change adaptation strategies, Guo et al. (2021) claimed that perceived temperature change can have a significant impact on farmer's adaptive behaviour. However, it should also be noticed that farmers' perception of climate change is usually aligned with observed real climatic trends in specific regions (Ogalleh et al. 2012; Alam et al., 2017; Bauer et al., 2022).

3. METHODS AND DATA

3.1. Study area

The Veneto Region is located in the North-East of Italy. It is characterised both by several PDOs and PGIs produced in the area, and by large climate change hazard, making this area perfectly suitable for studying adaptation to climate change and for obtaining insights which might be expanded to agricultural areas in other temperate regions of the EU.

Veneto is among the first Italian regions in terms of the economic impact of food GI, which amounted to € 433m in 2021, including about 800 economic agents. In the region, GIs represent 48% of the total agri-food sector (well above the national average, which is equal to 21%) (ISMEA-Qualivita, 2022). Moreover, in the Veneto Region, 36 different agri-food GIs (18 PDOs and 18 PGIs, respectively) can be produced, according to the PSs that set the boundaries for the production of each GI. Among them, there are some of the GIs with the highest production value in Italy, e.g., Grana Padano cheese, Asiago DOP cheese. Moreover, both crop-based GIs and animal-based GIs are produced. Among crop GIs, there are fruits and berries (e.g., cherries, chestnuts), vegetables (e.g. radicchio chicory, asparagus), and olive oil. Animal-based GIs include processed meats (e.g., ham), cheeses, and honey.

At sub-regional level, the production areas mainly concentrate in the NUTS3 regions (*province*, in Italian) of Treviso, Verona, and Vicenza, where some municipalities are eligible for the production of more than 9 different GIs each (Fig. 1).

In addition to the widespread diffusion of GIs, the Veneto Region is also highly prone to climate change (Pagliacci and Salpina, 2022), having experienced a rapid increase in average temperatures (Regione Veneto, 2021), since the 1990s. In particular, when comparing the decades 1961–1970 and 2009–2018, temperature

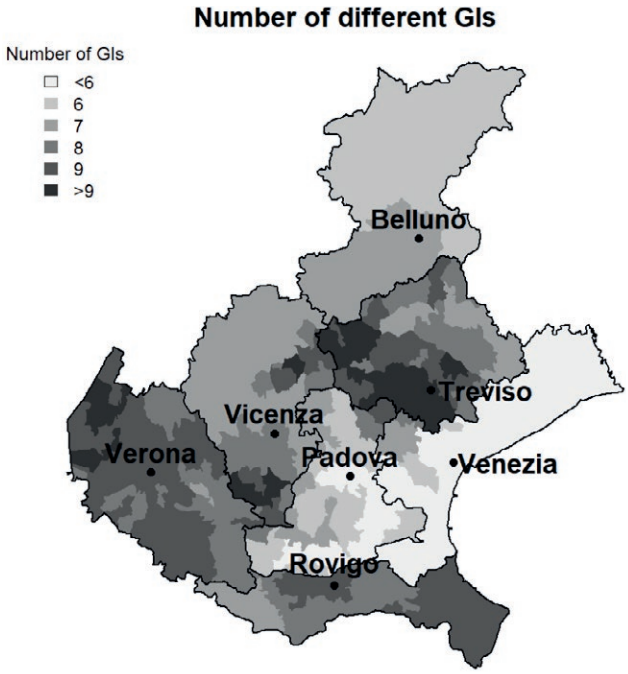

Figure 1. Distribution of the GI production areas across the region.

increase has been large across the entire Veneto region, ranging from a minimum increase of less than +1°C in the plains near the Adriatic Sea to an increase of more than +3°C in some areas of the Alpine region (Pagliacci and Salpina, 2022). In terms of rainfall, there has been a significant change in precipitation patterns. Although the region's annual total precipitation has not changed widely, there has been an increase in both the maximum annual values of short-term rainfall, on the one hand (Sofia et al., 2017), and in the frequency, length, and severity of droughts and related heat spells, on the other (Bonzanigo et al., 2016). In general terms, it can be observed that climate variability has increased, with a large number of extreme events (e.g., heavy rainfall, strong winds, hailstorms…) observed in almost every municipality of the region, in the decade 2010–2020. Given these characteristics, climate change hazard can be considered high across the whole region, with almost all agri-food sectors being largely affected (Pagliacci and Salpina, 2022).

3.2. Data collection

To answer the research questions, primary data was collected using a questionnaire-based online survey administered to agri-food GI producers in the study area.

Consortia or Producer Organisation (POs) helped in identifying respondents. As not all of them agreed upon providing a full list of producers, due to privacy reasons, they were asked to send the questionnaire directly to their members/producers, or alternatively information available online were considered. After a pilot phase (December 2021), the entire survey was administered between January and August 2022. Comprehensively, 183 responses were collected, with 46 of them being discarded after the first data cleaning. Thus, the final database includes data from 137 producers that answered all the questions necessary for the analysis.

Among the respondents, 29 producers of animal-based GIs[1] and 108 producers of crop-based GIs participated in the survey. It is approximately 18% of the overall population of GI producers located in the region[2], excluding the producers of the raw materials. The sample size – ranging from 5 to 15% – can be considered as adequate for a household survey (Bartlett et al., 2001; Alam et al., 2017).

All agri-food GIs factually produced in the region were considered in this study. To further classify them, the current analysis refers to the clusters of agri-food GIs of the Veneto Region identified by Salpina and Pagliacci (2022a) on a broad set of variables (i.e., type of GI, category, total revenue, decade of registration, share of production occurring in the region). Their classification returned six clusters of GIs. Three of them include PDOs only, distinguished according to revenue, territorial concentration at the local level and decade of registration ("Little revenue PDOs"; "Large-scale PDO cheeses"; "Second-generation PDOs"). The remaining clusters include PGIs (the "Unexploited opportunities", namely GIs for which the production in Veneto is actually nil; "First-generation crop PGIs", i.e., early PGIs, with higher revenue; "Second-generation crop PGIs with little revenue", i.e., PGIs with little turnover, more territorially concentrated, and registered more recently) (Salpina and Pagliacci, 2022a). In the current analysis, all the clusters were considered, with the only exception of the 'unexploited opportunities', given that the four meat-based PGIs included are not produced in Veneto. Actually, the focus on clusters, rather than on single products, enables us to provide information that can be useful for GI products

[1] In the case of animal-based GIs, producers of the final products (e.g., cheesemakers) were surveyed, asking them to report also details about their suppliers. Except for a few large dairy companies, often cheesemakers were also milk-producers, hence able to provide first-hand information. Moreover, the answers of a few cheesemakers producing 2 GIs were duplicated.

[2] The total number of producers for all GIs is not available. According to the authors' estimations based on data of Qualivita and numbers provided by Consortia, there are approximately 800 producers of agri-food GIs in the region (around 700 in the case of crop-based, and around 100 for animal-based GIs), excluding the producers of raw materials, i.e., only milk or meat producers.

with similar characteristics (e.g., size of production area, total turnover).

With regard to the contents of the survey, the questionnaire addressed a broad series of topics: farm management and networks, GI production, perception about climate change, implementation of adaptation measures, barriers to adaptation, additional socio-demographic information of the respondents. Some of those questions were used to retrieve some core variables for the econometric model (see the following section 3.3). This includes the questions on socio-demographic characteristics, farm management and network, product characteristics, and climate change perception and adaptation decisions (i.e., those mentioned in the theoretical background section). Additional questions included in the survey were instead used as ancillary variables to enhance the primary findings of the study, through some additional descriptive statistics. Among others, they include the questions on the impact of extreme weather events on agri-food GIs, on adaptation measures implemented or planned to be implemented by producers and on cost-effectiveness evaluation of these measures, as well as on barriers to adaptation.

In particular, the adaptation practices proposed in the questionnaire are based on the results of Salpina and Pagliacci (2022b), who had used semi-structured interviews and focus-group discussions involving managers of Consortia and POs in the same study area to understand how agents involved in agri-food GIs production are adapting to climate change.

3.3. The econometric model

Firstly, preliminary descriptive statistics are analysed, considering: observations on climate change, extreme events and adaptation practices, distinguishing between crop and animal-based GIs.

Secondly, the main drivers of adaptation of GIs producers to climate change are analysed through econometric models. As a dependent variable, the analysis considers the implementation of adaptation strategies by GI producers. In particular, three alternative situations are distinguished: (i) the one in which producers have already implemented adaptation strategies at the farm level; (ii) the one in which producers are willing to implement them in the next future; (iii) the one in which producers neither have implemented them in the past nor are willing to do so in the future.

A set of covariates is considered to analyse the occurrence of the different situations (Table 1). The table bases on the theoretical background presented in Section 2, thus distinguishing the core variables in terms of socio-demographic characteristics of the producers, farm management and networks, production characteristics, magnitude and perception of climate change. Lastly, a control variable (altitude) is considered as well, by distinguishing farms in the lowlands, hills, and mountains.

All these factors affect farmers' decision to implement adaptation strategies. To test this hypothesis, a comprehensive multinomial model is used. In particular, we estimate five different models:

$$Y = \beta_p P + \beta_a A + \varepsilon \tag{1}$$

$$Y = \beta_f F + \beta_a A + \varepsilon \tag{2}$$

$$Y = \beta_d D + \beta_a A + \varepsilon \tag{3}$$

$$Y = \beta_c C + \beta_a A + \varepsilon \tag{4}$$

$$Y = \beta_p P + \beta_f F + \beta_d D_e + \beta_c C + \beta_a A + \varepsilon \tag{5}$$

Where:

- **Y** is the (*n x 3*) matrix, where n = 137 respondents, indicating the alternatives decisions about adaptation (No, Yes, Yes in the future), and assuming the unwillingness to implement any adaptation strategies (both in the past and in the future) as the reference baseline.
- **P** is the (*n x 3*) matrix of the proxies of the socio-demographic characteristics of producers (including age range, sex and education level) and is the (*3 x 1*) vector of respective unknown parameters.
- **F** is the (*n x 2*) matrix of the proxies for farm management (i.e., full-time/part-time activity) and the number of farm adhesions, or networks the farm is involved in, such as POs and associations (e.g., CIA – Confagri) and is the (*2 x 1*) vector of respective unknown parameters.
- **D** is the (*n x 3*) matrix of the proxies for the product characteristics (type of certifications, clusters, and type of product) and is the (*3 x 1*) vector of respective unknown parameters.
- **C** is the (*n x 3*) matrix of the proxies for climate change variables, encompassing both variations in mean temperature between 2009-2018 and 1961-1970, and producer perception of climate change and extreme events in the production area. Additionally, is the (*3 x 1*) vector of respective unknown parameters.
- **A** is the (*n x 1*) vector of control variables about altitude and is the (1 x 1) unknown parameter.
- **ε** is the (n x 1) vector of error terms.

Table 1. Classification of the core variables considered for the analysis of the factors of adaptation.

Factor	Label	Levels (when categorical)
Socio-demographic characteristics	Age	0 = Less than 35
		1 = 35-44
		2 = 45-54
		3 = 55-64
		4 = more than 64
	Sex[a]	1 = Male
	Education level	0 = Elementary school
		1 = Middle school
		2 = High school (agrarian)
		3 = High school (non-agrarian)
		4 = University degree (agrarian)
		5 = University degree (non-agrarian)
Farm management and networks	Farm management	1 = Part-time
	Nr. of adhesions (memberships to different networks)	Continuous
Product characteristics	Cluster, according to Salpina and Pagliacci (2022a)	0 = Custer “Little revenue PDOs”
		1 = Custer “Large-scale PDO cheeses”
		2 = Custer “Second-generation PDOs”
		3 = Custer “First-generation crop PGIs”
		4 = Custer “Second-generation crop PGIs with little revenue”
	Certification type (PDO vs. PGI)	1 = PGI
	Type of the product	1= Crop-based
Climate change	Climate change observation in the production area	1 = Yes
	Observation of extreme events in the production area	1 = Yes
	Long-term temperature change (Difference in °C of the mean temperature of the period 2009-2018 and the mean temperature of the period 1961-1970)[b]	Continuous
Control factor	Altitude	0 = Mountains 1 = Hills 2 = Lowlands

[a] The research uses a binary sex categorisation (male/female), as a set of biological attributes associated with physical and physiological features.
[b] Data refers to the municipality where the producer is located. Data retrieved and adapted by https://climatechange.europeandatajournalism.eu/en/about (see Ferrari and Gjergji, 2020, for further methodological details).

The implementation of the models was performed by using the software R (R Core Team, 2021).

4. RESULTS

4.1. Characteristics of respondents

All the statistics about the socio-demographic characteristics of the producers, farm management, and product type characteristics under consideration in this study are shown in Table 2 and commented in this subsection. The following subsection 4.2 will focus on magnitude and perception of climate change.

With regard to the geographical distribution of the respondents, most of them are from the NUTS-3 regions of Treviso (30%), Verona (23%), and Vicenza (19%) which also host the largest number of agri-food GIs in the region (Fig. 2).

In terms of socio-demographic characteristics of the producers, most of the respondents are young producers. The rate of female respondents (23%) is low, but somehow similar to the share of women who are agricultural holders in the Veneto Region (26% of the total, according to Istat, 2022). The largest share of respondents has a diploma of non-agrarian high school, followed by those with a university degree in non-agricultural field.

With regard to farm management and networks, respondents are mostly full-time farmers, with only 38 out of 137 being part-time farmers. They are small-size farms, 50% of the total cases being family-run. Moreo-

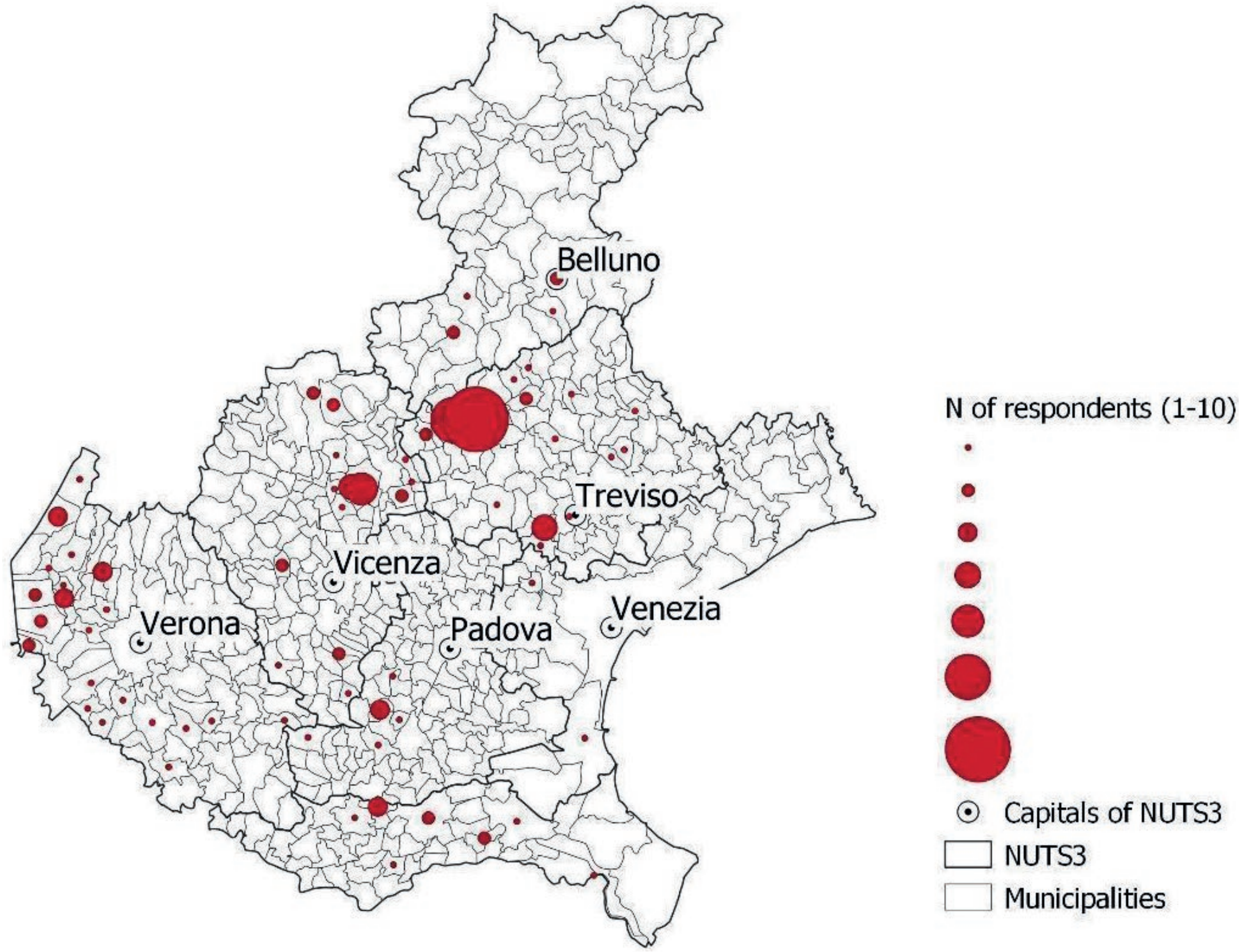

Figure 2. Geographical distribution of the sample.

ver, they are also members of only 1.66 networks on average.

When considering the characteristics of the produced GIs, most respondents are crop-based GI producers (108 out of 137), and PGI producers (63 out of 137). With regard to the 6 GI cluster classification by Salpina and Pagliacci (2022a), most of the respondents belong to the cluster of "Second-generation crop PGIs", "Little revenue PDOs", and "Second-generation PDOs", which include the largest number of agri-food GIs.

4.2. Climate change magnitude and perception and adaptation practices

With regard to climate change, data on long-term temperature change provided by Ferrari and Gjergji (2020) and some of the ancillary variables collected in the survey help to better characterise the sample. On average, the set of the municipality in which the respondents are located have experienced an increase of +2.7 °C, when comparing the period 1961-1970 and the period 2009-2018. Thus, 95% of the respondents producing crop-based GIs and 86% of the respondents producing animal-based GIs had direct experience of climate change in the production area. The main concern for both groups is an increased irregularity of precipitation (80%, on average), followed by temperature increase (72%, on average) (Fig 3). In terms of extreme weather events, 73% of the respondents have directly observed them in their production areas, over the last decade. On average, the impact of the extreme events under consideration in this research is evaluated as medium, except for frost, which seem to have the lowest effect among the respondents. Producers of animal-based GIs reported also a high impact of drought (Table 3).

Table 2. Producer, farm, and production characteristics of the respondents (137 total respondents).

Factor	Label	Levels (when categorical)	Value	Missing values
Socio-demographic characteristics	Age	0 = Less than 35	17	24
		1 = 35-44	25	
		2 = 45-54	30	
		3 = 55-64	19	
		4 = more than 64	22	
	Sex	1 = Male	81	25
	Education level	0 = Elementary school	1	24
		1 = Middle school	20	
		2 = High school (agrarian)	11	
		3 = High school (non-agrarian)	43	
		4 = University degree (agrarian)	10	
		5 = University degree (non-agrarian)	29	
Farm management and networks	Farm management	1 = Part-time	38	38
	Nr. of adhesions (memberships to different networks)	Average number (std. Dev.)	1.66 (1.15)	0
Product characteristics	Cluster, according to Salpina and Pagliacci (2022a)	0 = Custer "Little revenue PDOs"	29	0
		1 = Custer "Large-scale PDO cheeses"	18	
		2 = Custer "Second-generation PDOs"	27	
		3 = Custer "First-generation crop PGIs"	16	
		4 = Custer "Second-generation crop PGIs with little revenue"	48	
	Certification type (PDO vs. PGI)	1 = PGI	63	0
	Type of the product	1= Crop-based	108	0

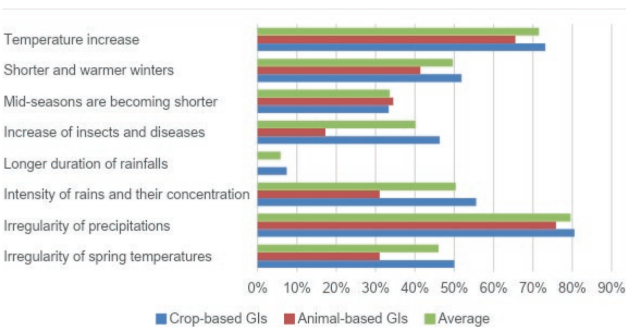

Figure 3. Observations on climate change.

More specifically, among the effects of climate change on crop-based GIs, respondents pointed out the effect on the volume of production and water availability. Conversely, the perceived effect on soil quality is relatively lower. Among animal-based GI producers, the major concern is heat stress, affecting cattle and milk production during summer, with negative consequences in terms of both product quality and quantities produced.

Despite the large and direct experience of climate change, only 24% of the respondents have already adopted some types of adaptation measures to cope with climate change. Moreover, 33% of them are planning to adopt them in the next future.

Among the managerial measures, which are implemented by both crop-based GI producers and animal-based GI producers, insurances (45%) are the most popular anticipatory measures of adaptation, followed by the use of advisory services and training. Among more technical measures (namely, those specific to either crop-based GIs or animal-based GIs), introduction of new crop varieties (49%), followed by increased efficiency of pests (46%), irrigation (45%) and crop rotation (45%) are the ones most mentioned by crop-based GI respondents. As for the producers of animal-based GIs, they mostly opt for barn cooling systems to deal with heat stress of animals (34%), followed by importing forage from outside the production area (21%) (Fig. 4).

In terms of costs and effectiveness of adaptation measures, the ranking for managerial and technical adaptation measures of crop-based GIs is quite heterogeneous. For crop-based GIs, introduction of new irrigation systems and increased efficiency of pesticides were attributed the highest scores in terms of cost/effectiveness ratio (3.6/5.0), whereas pest increase received the lowest score (2.1/5.0). For animal-based GIs, the lowest

Table 3. Average impact of extreme weather events on agri-food GIs (as evaluated by producers, scale from 1 to 5)

	Impact (Yes)	Drought	Frost	Hailstorm	Heavy rainfall/ Flood	Insects/ diseases outbreaks
Crop-based GIs	84/108	3.1	2.6	3.3	3.0	3.4
Animal-based GIs	16/29	3.7	2.3	3.5	3.1	3.3
Average	100/137	3.2	2.5	3.3	3.0	3.4

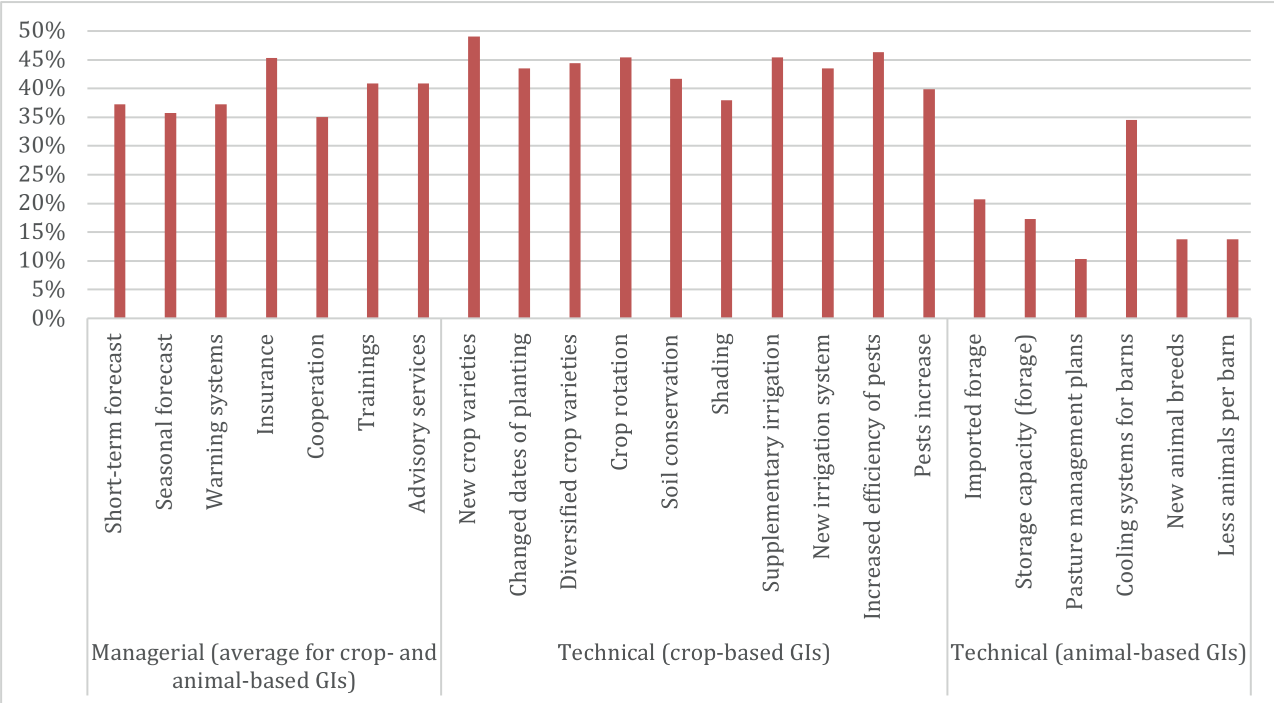

Figure 4. Adaptation methods implemented or planned to be implemented by producers of agri-food GIs.

score is for pasture management plans (1.0/5.0), while the highest one is for barn cooling systems (3.8/5.0) (Table 4).

4.3. Drivers affecting climate change adaptation

The factors influencing farmer willingness to implement adaptation measures are analysed under models (1)-(5) admitted in this study. Table 5 returns the results of these models.

In (1), which includes sociodemographic variables, education plays an important role. As expected, the respondents with a high school degree in agriculture show a greater willingness to adapt (either in terms of already-implemented adaptation strategies or in terms of future adaptation). Conversely, age is never significant. In (2), part-time management negatively affects adaptation decisions, while larger number of adhesions to associations and other sectoral networks couples with a higher probability of having already introduced some forms of adaptation practices. When considering production features, in (3), no covariates are significant. In (4), direct perception of the effects of climate change plays a major role in driving adaptation decisions, while, as an unexpected result, an increase in average temperature in the production areas shows a negative coefficient. Lastly, when considering all covariates jointly, in (5), education level remains the main factor influencing on-farm adaptation to climate change. In particular, education in agrarian field is positively associated with adaptation strategies. It is also confirmed that part-time farmers are less willing to undertake adaptation measures. As for GI products, "large-scale PDO cheeses" (Cluster 2) show negative coefficients, in

Table 4. Average score of adaptation measures (as evaluated by producers, scale from 1 to 5).

Managerial methods of adaptation (average)	
Short-term forecast	3.0
Seasonal forecast	2.7
Warning systems	2.9
Insurance	3.2
Cooperation	2.7
Trainings	3.4
Advisory services	3.0
Involvement of external actors	2.7
Adaptation measures for crop-based GIs	
New crop varieties	2.8
Changed dates of planting	2.6
Diversified crop varieties	3.5
Crop rotation	3.5
Soil conservation	2.8
Shading	2.5
Supplementary irrigation	3.6
New irrigation system	3.6
Increased efficiency of pests	3.6
Pests increase	2.1
Adaptation measures for animal-based GIs	
Imported forage	2.3
Storage capacity (forage)	2.2
Pasture management plans	1.0
Cooling systems for barns	3.8
New animal breeds	2.8
Less animals per barn	2.0

terms of both current and future adaptation to climate change. Similarly, when considering the type of GIs, producers of crop-based GIs are less willing to adapt than those of animal-based GIs, both when considering already existing adaptation strategies and future ones. Nevertheless, adaptation to climate change remains significant among producers that do observe climate change in their production areas. In addition, altitude of the production areas only shows a small effect, suggesting a negative relation between flatland locations and adaptation strategies.

Table 5 also shows the results of the McFadden test (Hausman and McFadden, 1984), the Akaike Information Criterion (Sakamoto et al., 1986), and the Bayesian information criterion (Schwarz, 1978), computed for each model. Although the computed tests do not point to the full model (5), however it is the one with the largest accuracy ratio.

5. DISCUSSION

This study offered important insights into the extent of adaptation to climate change in the case of the high quality agri-food GIs of the Veneto Region (Italy). The results show that agri-food GI producers are highly aware of climate change, having experienced both its direct and indirect impacts. In the case of animal-based GI productions, mainly indirect impacts of climate change are observed (e.g., alteration in fodder quality and quantity). In the case of crop-based products, the spectrum of direct impacts seems to be larger. However, although producers are perfectly aware of climate change and of its effects on GI production, adaptation has not reached its full potential among them. Only 50% of the respondents have already adapted to climate change or are expressing their willingness to do so in the next future. In particular, their decisions seem to be driven by a large number of factors.

All the different types of admitted drivers (i.e., socio-demographic characteristics of producers, farm management, type of product, climate change observation) matter in predicting adaptation measures at the farm level. Producers with an educational degree related to agriculture, who adhere to sectoral networks, and who perceive more directly climate change in their production area tend to be more willing to adapt to climate change. These findings are consistent with previous studies that claim the critical role played by risk perceptions (Fishbein and Ajzen, 2010; Grothmann and Reusswig, 2006; Menapace et al., 2015; Hasan and Kumar, 2019; Zagaria et al., 2021), involvement in social networks (Bairagi et al., 2021; Bazzana et al., 2022) and education (Muench et al., 2021; Guo et al. 2021), when explaining adaptation attitudes. The counterintuitive negative relationship between magnitude of climate change and willingness to implement adaptation strategies (as observed in just one of the selected models) might be explained with the intuition that further decreases in economic profitability, due to global warming, could make any adaptation investments too costly compared to any potential future benefits.

However, among the most interesting findings, rigidity of the PS deserves specific attention. Indeed, it can be observed that some of the adaptation practices implemented by conventional farmers, either in Italy (Bonzanigo et al., 2016) or elsewhere (Song et al., 2019; Antwi-Agyei et al., 2021; Nor Diana et al., 2022), are also adopted by some of the producers of agri-food GIs in the Veneto Region. This is the case, for example, of some varietal improvements as well as by the introduction of barn cooling systems. The main difference in adap-

Table 5. Results of the models.

	(1)		(2)		(3)		(4)		(5)	
	Yes	Future	Yes	Future	Yes	Future	Yes	Future	Yes	Future
Sex (Male)	0.890	0.246							1.731	0.649
	(0.633)	(0.575)							(1.097)	(0.861)
Age (35-44)	-0.155	0.872							1.468	1.491
	(0.938)	(0.969)							(1.375)	(1.230)
Age (45-54)	0.245	1.592							0.803	1.900
	(0.956)	(0.983)							(1.393)	(1.262)
Age (55-64)	-0.118	0.768							1.302	0.782
	(0.983)	(1.023)							(1.608)	(1.443)
Age (over64)	-0.493	-0.156							0.034	0.055
	(0.893)	(1.023)							(1.494)	(1.232)
Education (Middle)	15.073***	12.502***							-	-
	(0.678)	(0.653)								
Education (High non-agrarian)	16.046***	13.403***							2.403*	1.792
	(0.456)	(0.458)							(1.417)	(1.172)
Education (High agrarian)	50.949***	49.297***							41.679***	42.209***
	(0.361)	(0.361)							(0.652)	(0.652)
Education (University non-agrarian)	14.830***	12.654***							1.021	2.380*
	(0.543)	(0.503)							(1.601)	(1.328)
Education6 (University agrarian)	17.094***	14.883***							1.840	2.804
	(0.976)	(0.966)							(1.841)	(1.726)
Farm management (Part-time)			-2.598***	-1.677***					-3.724***	-2.400**
			(0.755)	(0.643)					(1.173)	(1.033)
Nr. of adhesions			0.564*	0.244					0.514	-0.030
			(0.301)	(0.283)					(0.384)	(0.375)
Clusters CL2					0.994	1.316			-13.671***	-12.405***
					(1.164)	(1.230)			(1.588)	(1.543)
Clusters CL3					0.220	0.191			-0.611	1.232
					(0.750)	(0.748)			(1.580)	(1.491)
Clusters CL5					0.190	0.362			-1.094	-0.452
					(0.609)	(0.561)			(0.870)	(0.855)
Clusters CL6					-0.597	-0.444			0.211	0.419
					(0.458)	(0.412)			(0.739)	(0.673)
Certification type (PGI)					-0.408	-0.082			-0.883	-0.033
					(0.468)	(0.437)			(0.760)	(0.660)

(Continued)

Table 5. (Continued).

	(1)		(2)		(3)		(4)		(5)	
	Yes	Future	Yes	Future	Yes	Future	Yes	Future	Yes	Future
Type (crop)					0.950	1.431			-10.467***	-10.939***
					(0.868)	(0.950)			(1.419)	(1.416)
Climate change observation (Yes)							1.889*	0.731	7.088***	4.506***
							(1.047)	(1.002)	(1.675)	(1.519)
Observation of extreme events (Yes)							-0.007	0.767	-0.062	1.334
							(0.709)	-0.783	(1.355)	(1.326)
Long-term temperature change							-1.471**	-0.624	-1.494	0.146
							(0.735)	(0.695)	(1.238)	(1.106)
Altitude (hills)	-0.312	-0.121	-1.136	-1.006	-0.463	-0.399	0.278	-0.266	-1.277	-1.545
	(0.856)	(0.801)	(0.937)	(0.820)	(0.860)	(0.820)	(0.870)	(0.771)	(1.462)	(1.342)
Altitude (lowlands)	-0.094	-0.093	-1.746*	-1.445	0.276	0.015	0.061	-0.351	-2.572*	-1.920
	(0.880)	(0.829)	(1.020)	(0.917)	(0.840)	(0.804)	(0.840)	(0.758)	(1.388)	(1.280)
Constant	-16.063***	-13.910***	1.382	1.814*	-0.606	-0.872	1.889*	0.731	7.088***	4.506***
	(1.033)	(1.012)	(1.109)	(1.021)	(1.085)	(1.137)	(1.047)	(1.002)	(1.675)	(1.519)
Obs.	106		93		115		99		86	
AIC	253.56		196.86		273.61		229.16		218.17	
BIC	322.81		222.18		317.53		255.11		321.25	
McFadden	0.13		0.13		0.04		0.04		0.29	
Accuracy	53.77		49.46		49.57		42.42		63.95	

Notes: statistically significant *p<0.1; **p<0.05; ***p<0.01.

tation strategies between agri-food GI producers and conventional ones is the existence of regulative barriers imposed by PSs. However, the fact that the certification type (i.e., producing either a PDO or a PGI) is never significant might suggest that rigidity of code of practices (i.e., more stringent PSs in the case of PDOs than in the case of PGIs) is not a big issue in climate change adaptation for GI producers. This finding seems to be supported also by the analysis of the main barriers, according to the respondents' perspectives (Table 6). Indeed, the restriction imposed by PSs is one of the least perceived concerns by producers, who are worried much more by the lack of financial resources or by difficulties in having access to public funds (e.g., those of the Rural Development Policy). Moreover, information issues seem to play a key role in the adaptation process.

Similarly, to what is observed across Europe (Simonet and Leseur, 2019) or elsewhere (Alam et al., 2017; Belay et al., 2022), the economic aspect of adaptation is proved to matter, as on-farm adaptation mostly relies on producers' own resources. On top of that, there is an issue of uncertainty, associated with the high cost of investments, and with the uncertain long-term benefits. In other words, uncertain future costs of climate risks compared to the certain and immediate costs of adaptation measures together with uncertain expected returns on investment represent one of the major barriers to climate change adaptation (Lefebvre et al., 2014), also in the case of agri-food GI producers.

Table 6. Barriers to climate change adaptation, as perceived by producers of agri-food GIs (as evaluated by producers, scale from 1 to 5).

Barriers (Number of respondents)	Adaptation			
	No (40)	Yes (33)	Yes_ future (45)	Total (118)
Lack of financial resources	3.6	3.1	3.9	3.6
High cost of investments and long-term benefits	3.9	3.2	3.5	3.5
Accession to RDP funds	3.6	3.9	3.8	3.7
Long waiting time for the accession RDP funds	3.8	3.5	3.9	3.7
Lack of technical assistance	3.4	3.0	3.4	3.3
Lack of information on effectiveness of certain adaptation measures	3.8	3.5	3.8	3.7
Restriction imposed by PSs	3.5	3.1	3.2	3.3
Land property	2.8	2.4	2.8	2.6
Lack of local and production networks	2.1	2.8	2.5	2.5
Lack of producers' representation in the decision-making process	3.3	3.3	3.3	3.3

The barriers discussed above couple with external factors, mainly involving policy and governance issues: observed complexity in having access to public funds, a lack of technical assistance in obtaining such help, market dynamics and the current geo-political conditions. In this context, climate change adaptation, which is of utmost importance given the impacts already affecting GI farmers and producers, seems to require specific policy interventions.

6. POLICY IMPLICATIONS

The results of this study represent an important contribution, not only to inform policymakers at regional level (i.e., in the Veneto Region), but also for national and EU policymakers and stakeholders. Indeed, the results of this study are highly generalizable in terms of suggested approach and adopted empirical strategy. In particular, the suggested strategy, distinguishing three alternative situations (farmers who have implemented adaptation strategies; farmers intending to implement them in the future; and farmers neither having implemented nor willing to do so in the future) holds promise for delivering a relatively elevated degree of accuracy and interpretability, also when implemented in other case studies.

Moreover, the results suggest that the main policy instruments for high-quality agri-food products might be largely improved across the EU. Firstly, a more targeted support within the new Common Agricultural Policy (2023–2027) will largely help. This is true also in a region such as Veneto, where in the 2014-2020 programming period just 1.5% of the total funds of the Rural Development Programme was earmarked to the measure aimed at supporting quality schemes (i.e., measure 03).

Besides a larger public fund allocation, in this context, reliability of new technologies and clear information regarding their effectiveness might help. This will provide new incentives to the producers of agri-food GI, when considering their options of investing in new adaptation measures to climate change. Moreover, it could also be helpful developing peer-to-peer learning practices among producers together with fostering further collaborations among GI systems that face similar risks. Indeed, the role of public policies is not limited to allocation of financial resources to prevent the financial barriers of adaptation, but it can also ease knowledge transfer (Ignaciuk, 2015), fostering collaborations between farms and Consortia, and across sectors (e.g., public and private). To this regard, the framework of Agricultural Knowledge and Innovation Systems (AKIS) could be strengthened, in terms of a multi-stakeholder process (Cruz Maceín et al., 2023). Analogously, also the functions of Consortia and POs could be strengthened to better facilitate the coordination among the stakeholders for the implementation of adaptation strategies at GI level. These entities, which frequently offer advisory support, can serve as innovation intermediaries, cooperating with research organisations (Salpina and Pagliacci, 2022b) and facilitating horizontal and vertical diffusion of information. Thus, Consortia and POs can play a pivotal role in sustaining adaptation efforts, and guide farmers in investing in new adaptation measures. Lastly, the findings of this empirical study hold the potential to contribute significantly to international discourse surrounding food policy, by providing an in-depth examination of climate change adaptation practices within the GI agri-food sector, the policy area that has thus far received limited attention within academic circles.

7. CONCLUSION

This study aimed at analysing climate change adaptation strategies in the case of high-quality agri-food sector, shedding light on the main factors influencing the decision of producers to adapt. In the past, this topic was largely neglected in the literature. Actually, to the authors' best knowledge, only a few other studies have already focused on the topic of climate change adaptation, taking agri-food GIs into consideration. The key findings of the research suggest that despite a generalised (and high) awareness of climate change among GI farmers and producers, this has not yet turned into widespread adoption of adaptation measures. The main factors influencing the willingness of producers are confirmed to revolve around the complex interplay of socio-demographic characteristics (e.g., age, education), farm management and networks, and production characteristics, in addition to the perception of climate change.

Despite the potential limitations of any online surveys (e.g., some bias in respondents' characteristics, in favour of younger and more educated ones), further studies could eventually replicate the questionnaire-based survey in other countries and regions, making use of the same methods proposed here. Moreover, it should be noticed that this study encompassed the certified agri-food sector in general. Thus, future works, focusing on a specific sector (e.g., only cheese products), would allow for a more targeted examination of key variables affecting climate change adaptation. One additional limitation of this study is the absence of a comparison between farmers operating within GI schemes and the ones operating outside such schemes. However, such a limitation was due to the complexity of such a comparison and mostly to the data collection process, which was primarily done through Consortia and POs. Future research will eventually address this gap, providing valuable insights into this phenomenon. Moreover, future lines of research will also involve the analysis of the drivers contributing to the adoption of specific adaptation measures and will consider additional and more sophisticated proxies for climate change perception.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support from the project "What if the terroir moves under our feet? Addressing the effects of climate change on the use of geographical indications for agri-food products in Veneto, Italy" (PAGL_BIRD20_05 - BIRD 3 2020/2022 research grant). Project financed with BIRD 2020 funds, Department TESAF, University of Padova - Italy. The authors thank the editor and the anonymous referees for their precious suggestions that have led to a great improvement in the overall quality of the paper.

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