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# Smart farming in mountain areas: Investigating livestock farmers' technophobia and technophilia and their perception of innovation

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ABSTRACT

Smart farming technologies, such as information and communication technologies, can provide many advantages for farm management. Nevertheless, their diffusion is still limited, especially in mountainous areas. For this reason and considering the crucial role of mountain farming, public policies have begun to increasingly support innovation practices in these areas. The purpose of this study was to investigate how attitudes and the characteristics of farmers and farms influence the use of technological devices (i.e., smartphones, tablets and computers). The case study was set in the rural area of Valtellina in the Italian Alps, where 63 dairy farmers were interviewed. Cluster analysis was used to classify farmers, considering their levels of technophobia and technophilia as well as their perceived obstacles and motivations to use new technologies. Three different classes of farmers were thus identified: *technophobes*, *insecure technophiles* and *technophiles*. The results show that attitudes towards new technologies are affected by a farmer's age, education level, farm size, actual smartphone usage for professional duties, and optimistic behaviour towards the future of the farm. This study supports policy makers in developing tailored policies in support of mountain farmers and service providers, indicating future directions for the design of their products.

## 1. Introduction

A key concept introduced by the European Commission's (EC) "The future of food and farming" communication (2017) is that the next common agricultural policy (CAP) post-2020 reform must foster a smart agricultural sector. As pointed out by the EC, "smart farming" or "smart agriculture" represents the application of modern information and communication technologies (ICTs) to agriculture, leading to what can be called a "Third Green Revolution" (CEMA, 2019). ICTs include products and services that allow entrepreneurs to store, process, transmit, convert, duplicate, or receive electronic information. Among the ICTs for smart agriculture, farmers can adopt software and hardware solutions, such as professional applications and operating systems, mobile phones, remote sensors, and multimedia products (FAO, 2017). These technologies provide farmers with updated information, such as farms' input and yields and agricultural markets, promoting an increase in the efficiency of the farm production process through evidence-based managerial decisions (FAO, 2017; Bucci et al., 2018; Caffaro and Cavallo, 2019). Moreover, as reported by the FAO (2017), ICTs can promote learning and therefore facilitate technology adoption among farmers.

Despite the advantages provided by these technologies, in the last decade in the European Union (EU), only one out of four farmers adopted ICTs (Caffaro and Cavallo, 2019; CEMA, 2019). Furthermore, despite Italy being the first-ranked European country in terms of agricultural value added and the second-ranked in terms of production value (ISTAT, 2018; Eurostat, 2019), the last agricultural census (ISTAT, 2010) showed that only 76,000 out of 1.6 million farms adopted organizational innovations such as ICTs (Avolio et al., 2014). According to the European Innovation Scoreboard analysis (EC, 2019), Italy has moderate innovation performance compared to the other EU member states. In the agricultural sector, structural and cultural factors surely affect the innovation process, which is not uniform within Italy (Capitanio et al., 2010; Avolio et al., 2014; Bucci et al., 2019). Although the fostering of smart farming appears to be even more important for increasing the competitiveness of mountain farming, these mountainous areas show the highest aversion towards innovation (Avolio et al., 2014).

Mountain farming faces several natural and technological

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limitations. For instance, climatic conditions limit the length of the growing season and lead to the scarce accessibility of lands, the presence of slopes impedes the use of machinery (Santini, 2013), and poor mobile network coverage can hamper the use of ICTs (Riddlesden and Singleton, 2014; Dehnen-Schmutz et al., 2016). Such limitations imply some difficulties in the development of economies of scale and thus have a great impact in terms of increased costs and lower productivity compared to lowland agriculture. Despite these constraints, mountain farming's persistence and prevention of land abandonment are essential for protecting landscapes and ecosystems, reducing erosion and natural hazards (i.e., avalanches and floods), supporting the local economy and preserving local traditions (MacDonald et al., 2000; Dax, 2000; Santini et al., 2013; Cavicchioli et al., 2015; Mazzocchi and Sali, 2021). Considering the crucial role of mountain farming in the provision of public goods to society, special support programmes for mountain farmers have been developed in the CAP since the early 2000s, and the current public policies increasingly support innovative practices in these areas, encouraging farmers to adopt ICTs to ensure agricultural sustainability (MacDonald et al., 2000; Avolio et al., 2014). Despite all these efforts to promote ICT application in mountain farming, these technologies remain scarcely used in these areas (Avolio et al., 2014).

Scholars and institutions have widely recognized the importance of fostering smart farming for improving mountain farming competitiveness (Avolio et al., 2014); nonetheless, to the best of our knowledge, no previous studies on ICT adoption have been developed focusing on a sample of mountain farmers. By means of the clustering analysis method, the present study examines how attitudes and the characteristics of farmers and farms influence the use of ICT devices (i.e., smartphones, tablets and computers). The research questions are as follows:

1. Which attitudinal factors underlie mountain farmers' use of technological devices?
2. Which farmer classes can be derived from the differences in attitudes about the use of technological devices?
3. How do the characteristics of farmers and farms affect farmer clustering?

To the best of our knowledge, this is the first study clustering mountain dairy farmers based on their attitudes towards technologies. The results from this study are especially important considering the limited adoption and diffusion of ICTs among mountainous farmers. In fact, understanding the factors that affect the adoption of these technologies is fundamental for the development of tailored policies in support of different types of mountain farmers. Our results can also help service providers indicate future directions for the design of their products.

The remainder of this article is structured as follows. Section 2 presents a literature review focused on farmers' adoption of technologies and their attitudes towards innovation. Section 3 describes the methods and procedures that were implemented in the analysis, including the conceptual framework (Section 3.1), the case study (Section 3.2), sample and data collection (Section 3.3) and the data analysis (Section 3.4). Section 4 describes the results, while Section 5 provides a related discussion. Finally, Section 6 provides a summary of the research and some conclusions.

## 2. Farmers' adoption of technologies and innovation: background

Most of the literature on the factors affecting farmers' adoption of technologies and innovation in developed countries seems to be related to specific types of technologies (Long et al., 2016). For instance, Wheeler (2008) focused his study on the adoption of organic farming and genetic engineering practices in Australia. Additionally, in the Australian context, Sneddon et al. (2011) investigated farmers' adoption of new agricultural technologies in the wool sector. A number of studies have investigated the adoption of specific sustainable and pro-environmental agricultural innovations within the wine industry (Hughey et al., 2004; Bhaskaran et al., 2006; Marshall et al., 2010; Cullen et al., 2013) and more generally in land management (Rhodes et al., 2002; Curtis and Robertson, 2003; Griffiths et al., 2008). Tey and Brindal (2012) and Pierpaoli et al. (2013) investigated the factors influencing the adoption of precision agricultural technologies (i.e., yield mapping, remote sensing, and GPS) by summarizing the findings of past studies. In Italy, Cavallo et al. (2015) analysed the innovative attitudes of farmers towards the technological innovation of agricultural tractors.

More recent studies have focused on smart farming in general. For example, Long et al. (2016) explored the barriers to the adoption and diffusion of technological innovation for climate-related smart agriculture in Europe and specifically in the Netherlands, France, Switzerland and Italy. Carrer et al. (2017) investigated the factors influencing the adoption of farm management information systems by Brazilian citrus farmers. Morris et al. (2017), focusing on pastoral farmers across Wales, analysed the interconnectedness between farm diversification and technology adoption, with farm strategy as the central focus. Furthermore, Caffaro and Cavallo (2019) considered the roles of objective and subjective factors (i.e., education, farm size, being sole farmers and perceived barriers) in the adoption of smart farming technologies in a sample of Italian farmers from the Piedmont region (northwestern Italy). Finally, Gittins et al. (2020) investigated the benefits and challenges associated with the adoption of new farm management technologies and software adoption in the UK livestock sector.

Overall, these prior studies have suggested that the rate of adoption and perceived barriers relate to a specific innovation, to the farmer himself/herself and to the specific context (Sassenrath et al., 2008; Cullen et al., 2013). Factors depending on the specific type of innovation are related to (i) the financial costs and economic benefits expected from the adoption of the new technology; (ii) the risks connected with this adoption; (iii) the advantages in terms of prestige, convenience and satisfaction; (iv) its consistency with the needs of adopters; (v) the difficulties and complexity connected to the understanding and maintenance of the technology; and (vi) the observability of the innovation results (Cullen et al., 2013; Long et al., 2016). Factors related to the farmer are connected to his/her sociodemographic characteristics, with the most important of which affecting the adoption of new technologies being farmers' age, educational level, income, farm size, technological skills and actual use of technologies (Khanna, 2001; Adrian et al., 2005; Pierpaoli et al., 2013; Avolio et al., 2014; Caffaro and Cavallo, 2019). Finally, the adoption of new technologies is influenced by context-specific factors, such as political and social pressures, the national context and the regulatory environment (Tey and Brindal, 2012; Avolio et al., 2014; Long et al., 2016).

Although Adrian et al. (2005) and Adesina and Zinnah (1993) underlined that the omission of farmers' attitudes towards the adoption of technologies may lead to biased results, only a few studies in the agricultural sector have deepened the knowledge related to these topics, and all of them have focused on precision farming technologies (Adrian et al., 2005; Pierpaoli et al., 2013). According to the literature, the adoption of new technologies is influenced by an individual's general attitudes towards innovation and, more specifically, by technophobia and technophilia as well as the perceived obstacles and usefulness of technologies (Nickell and Pinto, 1986; David, 1989; Rosen et al., 2013; Martínez-Córcoles et al., 2017). Technophobia has been defined as "*an irrational fear and/or anxiety that individuals form as a response to a new stimulus that comes in the form of a technology that modifies and/or changes the individual's normal or previous routine in performing a certain job/task*" (Khasawneh, 2018), while technophilia has been defined as "*a strong attraction and enthusiasm for new technologies*" (Martínez-Córcoles et al., 2017). Perceived obstacles, or "perceived ease of use", refer to "*the degree to which a person believes that using a particular system would be free of effort*" (Davis, 1989). Moreover, in contrast, motivations to use, or "perceived usefulness", refer to "*the degree to which a person believes that using a particular system would enhance his or her job performance*" (Davis, 1989).

## 3. Method and procedures

### 3.1. Conceptual framework

The conceptual framework used in this study follows three main steps, as presented in Fig. 1. In the first step, we identify the psychological measures used to measure farmers' attitudes towards the use of technological devices. Based on the review of the literature concerning innovation adoption, three main theoretical constructs are adopted in the present survey: (1) technophobia and technophilia, (2) perceived obstacles, and (3) motivations to use. Then, in the second step, the clustering of the farmers is performed based on these three attitudinal determinants. Finally, in the third step, profiling variables related to the characteristics of farmers and farms, such as gender, age, educational level, farm size, smartphone usage, and expectations for the future of the farm, are used to describe the characteristics of the classes.

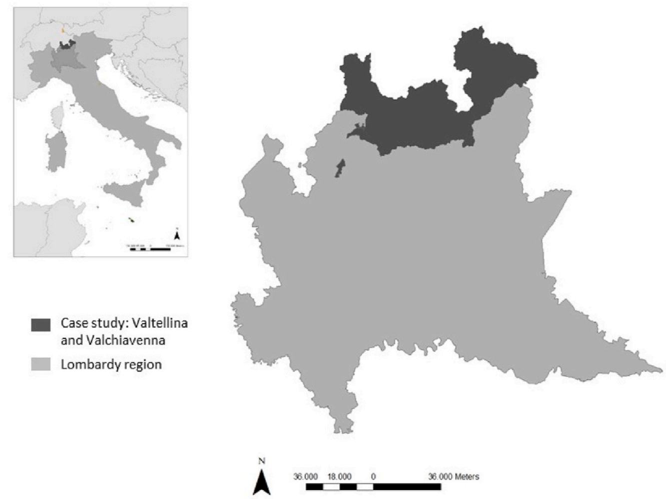


**Fig. 2.** Geographic location of the case study area.

### 3.2. Case study

This study was conducted in the mountainous rural area of Valtellina, Valchiavenna and Alto Lario in the Lombardy region, close to the border with Switzerland (Fig. 2). The area is characterized by a specific geographical conformation: the altitude varies from approximately 198 to 4000 m above sea level, and this area has a relevant east-west extension covering 3,212 km$^2$. More than 70% of the provincial territory is located 1500 m above sea level, and only a small portion (just over 1%) is urbanized. Most of the area is composed of natural and forest areas (88%), while the agricultural area covers only 7.4% of the total area (ERSAF, 2015).

Nonetheless, farming activities represent an important economic source of income in this area. In 2016, 17% of the companies belonged to the agricultural sector, second only to the commercial sector, which accounted for 21% (Camera di Commercio di Sondrio, 2016). The agricultural sector is also important for youth employment: 11% of young entrepreneurs operate a business in the agricultural sector, second only to tertiary companies (Camera di Commercio di Sondrio, 2016). Agriculture is mainly based on traditional products of animal origin, such as the Bresaola of Valtellina GPI, Bitto PDO and Casera PDO cheeses, which are marketed in national and international markets (EC, 2009). According to the last national census, livestock farms represented 44% of all farms, a percentage that seems in line with the average regional value (41%) (ISTAT, 2010). Despite their economic importance, the number of livestock farms decreased from 1982 to 2010, on average accounting for 35%, one of the highest rates in the Lombardy region compared to the other provinces. In this case study, among livestock farms, dairy farms showed the smallest decrease (−38%), and unlike sheep, pig and poultry farms, the decrease in the number of dairy farms has been partially accompanied by a decrease in the number of animals (10%), showing a general increase in farm dimensions and the withstanding of the dairy farming system (ISTAT, 2010). According to estimates, livestock products in the area account for approximately 63% of gross products sold, confirming the importance of bovine dairy farms for the local rural economy.

As is typical in the alpine landscape, farming activities are performed in valleys, which are characterized by the presence of stable meadows interspersed with cultivated fields, particularly those containing corn for fodder production, and at higher altitudes, the farming system is based on pastures. The integration of valley agriculture and mountain pastures based on dairy farming systems is still of economic value and of important cultural and identity significance for the whole territory, representing a significant environmental and naturalistic heritage (Provincia di Sondrio, 2016).

Compared to other areas in the Lombardy region, only approximately 6% of farms have declared, according to the last national census, that they use computers and ICT devices for farm management, while the regional average is approximately 17%. Farms tend to use ICTs more to manage administrative services (3.6%) and crop systems (2%) than to manage herd production (1.7%). In contrast, internet usage by farmers in the area is in line with the average regional value of 3% (ISTAT, 2010).

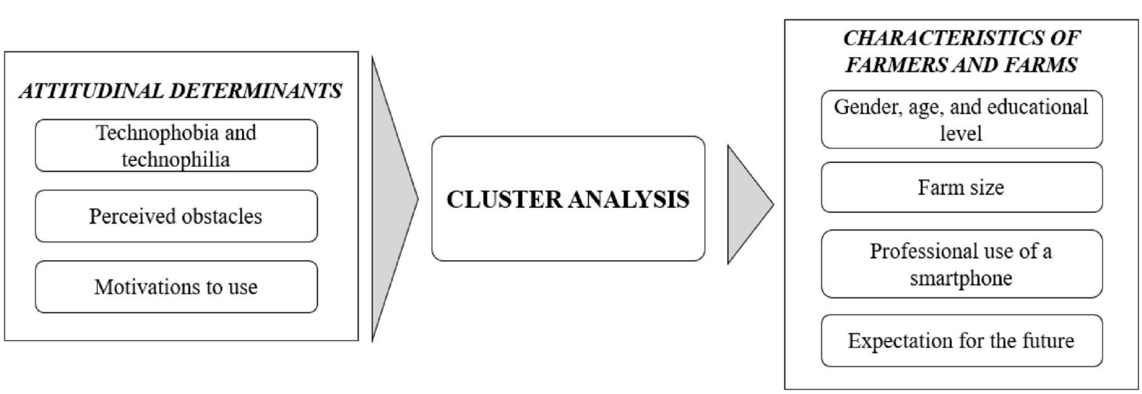


**Fig. 1.** Conceptual framework.

### 3.3. Sample and data collection

The survey data were collected through personal interviews from July 2019 to December 2019 with mountain farmers who were members of a dairy cooperative, with 88 members, that produces 25 million litres/year of milk. Participants were recruited with the assistance of the dairy cooperative and were interviewed personally at their farms. A pilot test on a sample of 5 dairy farmers was conducted to test the appropriateness of the questionnaire. The final sample consisted of 63 dairy farmers.

These farms are homogeneously spatially distributed in the overall area (Filippini et al., 2020), and they show homogenous characteristics in terms of farming practices. As is common in the area, these farms perform extensive farming practices, combining stable valley meadows in winter and high-altitude pastures in summer. The cropping system is mainly devoted to fodder to feed the herd. The majority of these farmers use smartphones on a daily basis (74.6%, $n = 47$). On average, these farmers have owned a smartphone for 3.57 years (*St. Dev.* = 3.19).

Table 1 shows the characteristics of the sample of respondents. Most of the respondents were male (85.7%) and aged between 40 and 54 years (47.3%). A total of 46.0% of the sample had completed middle school, while 42.9% had completed high school. Only 6.3% had obtained a bachelor's or master's degree. With respect to farm size, more than half of the sample had less than 50 cows under lactation (65.1%), 27.0% had from 50 to 100 cows, and only 8.0% of the sample had more than 100 cows. As shown in Table 1, the farmers from the cooperative seem to be younger and better educated than those farmers localized in other mountain areas. When asked, the cooperative managers confirmed that there had been important generational turnover in the last 10 years.

At the beginning of the interview, a brief explanation of the purpose of the study was provided to participants. The questionnaire was structured into two sections. The first section included questions on farmers' characteristics, such as their gender, age, educational level, farm size in terms of the number of cows, professional use of a smartphone and expectations for the future of their farm. To explore farmers' use of smartphones for professional duties, participants were first asked whether they owned a smartphone (yes/no) and for how long. Then, we provided a list of potential reasons for using a smartphone for farm management purposes (weather forecasts, communication via e-mail with other breeders, communication via e-mail with the dairy cooperative, social media consultation, and internet browsing) and asked participants to indicate for which reason they were using their smartphones. For each reason, respondents were asked to express their frequency of use using a scale ranging from 1 = *never* to 5 = *very often*. To avoid any bias, there was also the possibility for them to mention any other reason not included in the list. Furthermore, to assess farmers' expectations, participants were asked to rate how they see the future of their farms on a 5-point interval scale ranging from "*very pessimistically*" to "*very optimistically*".

**Table 1**
Characteristics of the sample compared to the Italian population.

| Item | Total sample (n = 63) | Lombardy region mountain farmers | Italian farmers |
|---|---|---|---|
| | (%) | (%) | (%) |
| *Gender* | | | |
| Male | 85.7 | 73.6 | 71.0 |
| Female | 14.3 | 26.5 | 29.0 |
| *Age group* | | | |
| Younger than 40 yrs. | 26.9 | 18.7 | 10.0 |
| 40–54 yrs. | 47.3 | 32.2 | 28.5 |
| 55–64 yrs. | 15.9 | 32.6 | 34.3 |
| 65 yrs Or older | 9.5 | 16.5 | 27.2 |
| *Educational level completed* | | | |
| Elementary school | 4.8 | 33.8 | 39.5 |
| Middle school | 46.0 | 37.5 | 32.0 |
| High school | 42.9 | 25.4 | 22.2 |
| University bachelor's or master's degree | 6.3 | 3.4 | 6.2 |
| *Size of farm* | | | |
| <50 cows | 65.1 | | |
| 50–100 cows | 27.0 | | |
| >100 cows | 8.0 | | |

Source: Italian Census of Agriculture (ISTAT, 2010)

The second section of the questionnaire sought to highlight the psychological measures that are expected to delineate farmers' attitudes towards the use of technological devices, such as technophobia and technophilia, perceived obstacles and motivations for use. Farmers' technophobia and technophilia were assessed by developing a specific scale considering the extant literature (Nickell and Pinto, 1986; Ratchford and Barnhart, 2012; Rosen et al., 2013), which combines several statements of the "Technophobia and Technophilia Questionnaire - TTQ" proposed by Martínez-Córcoles et al. (2017). The scale used in the current study was based on six items concerning farmers' technophobia and technophilia towards new technologies. A five-point Likert scale with responses ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) was used to record participants' responses. To investigate the perceived obstacles to the use of technological devices (i.e., smartphones, tablets and computers), based on the previous literature (Nickell and Pinto, 1986; David, 1989; Rosen et al., 2013), we developed a ten-item scale including the constraints that hamper the adoption of new equipment and technologies on farms. Participants were asked to express their agreement using a scale ranging from 1 = *strongly disagree* to 5 = *strongly agree* for each item. Finally, following the extant literature (Nickell and Pinto, 1986; David, 1989; Rosen et al., 2013), farmers' motivations to use technological devices were investigated by developing a scale with ten items concerning the most important benefits that farmers perceive from the use of technologies in their daily work and that may drive the farmers' adoption of new equipment and technologies.

### 3.4. Data analysis

The data were analysed using descriptive, bivariate and multivariate statistics. All statistical procedures were performed using IBM SPSS Statistics (SPSS Inc., Chicago, IL). The internal reliability consistency of the multi-item scales was tested using Cronbach's alpha (Cronbach, 1951; Peterson, 1994). To identify possible distinct groups of farmers with different attitudes towards the use of technological devices, the data were statistically analysed by means of cluster analysis. The mean scores of three factors analysed, which were calculated as the average of the items of each implied scale, were used as the clustering variables. As suggested in the literature (Bacher et al., 2004; Mooi and Sarstedt, 2011) and following previous farm systems studies (Kuivanen et al., 2016; Morris et al., 2017), a two-step clustering method was used to group respondents into the optimal number of clusters. The differences between clusters were assessed through one-way ANOVA *F* tests with Dunnett's T3 post hoc comparison of the means. Finally, the clusters were profiled in terms of farmers' characteristics. The differences between the clusters were investigated using cross-tabulation with $\chi^2$ for the categorical variables, Kruskal-Wallis statistics for the ordinal variables, and one-way ANOVA *F* tests for the scalar variables.

## 4. Results

### 4.1. Frequency of use of smartphones and farmers' expectations for the future

The results regarding the frequency of use of smartphones for professional duties are reported in Table 2. Farmers' frequency of use of smartphones is quite low, with a mean value of 2.53 on a 5-point scale (*St. Dev.* = 1.05). Seeking weather information and forecasts was the most popular professional smartphone activity among farmers (mean value = 3.79, *St. Dev.* = 1.69). Of the respondents, 58.7% declared that they sought weather forecasts on their smartphones very often, while 11.1% did so quite often. Smartphones are also often used by farmers to

**Table 2**
Frequency of use of smartphones for professional duties among farmers.

| | Never (%) | Rarely (%) | Sometimes (%) | Often (%) | Very often (%) | *Mean* | *St. Dev.* |
|---|---|---|---|---|---|---|---|
| Acquire weather forecasts | 23.81 | 1.59 | 4.76 | 11.11 | 58.73 | *3.79* | *1.69* |
| Communication via WhatsApp with other breeders | 38.10 | 9.52 | 14.29 | 19.05 | 19.05 | *2.71* | *1.59* |
| Communication via email with other breeders | 63.49 | 22.22 | 9.52 | 1.59 | 3.17 | *1.59* | *0.96* |
| Communication via email with the dairy cooperative | 42.86 | 14.29 | 22.22 | 7.94 | 12.70 | *2.33* | *1.43* |
| Consulting social media (Facebook, Twitter, etc.) | 57.14 | 17.46 | 12.70 | 6.35 | 6.35 | *1.87* | *1.24* |
| Internet browsing | 34.92 | 7.94 | 12.70 | 25.40 | 19.05 | *2.86* | *1.58* |
| ***Total*** | | | | | | ***2.53*** | ***1.05*** |

browse the internet (mean value = 2.86, *St. Dev.* = 1.58) and for communication with other farmers via WhatsApp (mean value = 2.71, *St. Dev.* = 1.59). Conversely, farmers declared that they used their smartphones less for communication via email with the dairy cooperative (mean value = 2.33, *St. Dev.* = 1.43) and for consulting social media such as Facebook and Twitter (mean value = 1.87, *St. Dev.* = 1.24). Using a smartphone for communications via email with other farmers was the least frequent activity (mean value = 1.59, *St. Dev.* = 0.96), with 63.5% of the respondents stating that they had never used their smartphones for this purpose and 22.2% stating they had used them rarely for this purpose.

The survey also included a question aimed at assessing farmers' expectations for their professional future (Table 3). Farmers were generally optimistic (mean value of 3.25 on a 5-point scale, with a standard deviation of 1.16). Specifically, a significant portion of the sample (39.7%) considered themselves to be optimistic or very optimistic, while 41.3% considered themselves to be neither pessimistic nor optimistic concerning the future of their activities. Moreover, 11.1% of the respondents declared that they were very pessimistic regarding the future of their farms.

### 4.2. Farmers' attitudes towards the use of new equipment and technologies

The second section of the survey focused on farmers' attitudes towards the use of technological devices, i.e., technophobia and technophilia, perceived obstacles and motivations to use. Cronbach's α test was used to estimate the internal reliability consistency and validate the implied multi-item scales. All three scales exceeded the minimum standard of reliability (Cronbach's $\alpha > 0.600$), demonstrating that they are valid instruments for measuring the proposed construct (Cronbach, 1951; Peterson, 1994; Verbeke and Vackier, 2004). The highest value was obtained by the scale for motivations to use (Cronbach's $\alpha = 0.874$), followed by the scale for perceived obstacles (Cronbach's $\alpha = 0.840$) and, finally, by the scale for technophobia and technophilia (Cronbach's $\alpha = 0.787$). Each investigated construct was calculated as the average score across items.

Table 4 presents an overview of the results for the technophobia and technophilia questions answered using a Likert scale. The sample results were quite low, with a mean value of 2.79 (*St. Dev.* = 0.95), indicating that farmers, in general, are not averse to and do not have negative feelings towards modern technologies. More than half of the respondents disagreed with the statements "I feel an irrational fear of new equipment or technology" (60.3%, mean value = 2.02) and "I avoid the use of new equipment and technology" (58.7%, mean value = 2.35). However, 30.1% of the farmers admitted that they were not excited for new equipment and technology (mean value = 2.83), and 32.0% of them stated that they did not enjoy using new equipment and technology (mean value = 2.84). Moreover, 73.0% of the sample declared that they were not afraid of being left behind if they could not use the latest equipment or technology (mean value = 4.22).

Table 5 reports the results of the scale regarding the perceived obstacles to the use of new equipment and technologies. Participants showed that they perceived a moderate degree of obstacles to the use of technologies, with a mean value of 2.54 on a 5-point scale (*St. Dev.* = 0.84). The major obstacles to the adoption of new technologies perceived by farmers were their costs (31.7%, mean value = 3.48). This finding is consistent with those of previous studies identifying financial costs as the core barrier to the adoption of new technologies (Wheeler, 2008; Sneddon et al., 2011; Long et al., 2016). Other perceived obstacles were the belief that such technologies distance the farmer from the care of animals and crops (17.5%, mean value = 2.41) and that they demand too much time (14.3%, mean value = 2.94). Moreover, a relevant proportion of respondents perceived that these technologies might not offer the same precision as does manual labour (50.8%, mean value = 2.19), that there are no clear benefits from their use (50.8%, mean value = 2.03) or that they have a slow and/or absent internet connection (46.0%, mean value = 2.11) as the possible obstacles to the adoption of such technologies.

Finally, farmers' motivations for using new equipment and technologies are reported in Table 6. The sample results were quite high (mean value = 3.42, *St. Dev.* = 0.84), indicating that participants generally have a positive view and perceive numerous motivations and benefits connected to the adoption of technologies. Overall, 42.9% of the respondents believe that the major driver of their adoption of new technologies is the fact that these technologies may make an important contribution by monitoring production parameters (mean value = 3.98). Moreover, 31.7% of respondents (mean value = 3.75) believe that these technologies may help fulfil production regulations, such as CAP and production specification standards, and 30.2% of them (mean value = 3.75) believe that they may contribute to managing breeding in a more conscious way. In contrast, reduced production costs (27.0%, mean value = 2.49) and improved work comfort (20.6, mean value = 3.11) are not perceived by farmers as possible motivations for the use of new equipment and technologies.

### 4.3. Cluster analysis

Based on the mean scores of the three factors studied, obtained from the applied multi-item scales, two-step cluster analysis was performed to verify the existence of homogeneous groups of farmers with different attitudes towards the use of technological devices. A total of three clusters of farmers were identified as optimal solutions. One-way analysis of variance (ANOVA) was performed to compare the factor mean

**Table 3**
Farmers' expectations for the future of their farms.

| | Very pessimistic (%) | Pessimistic (%) | Neither pessimistic nor optimistic (%) | Optimistic (%) | Very optimistic (%) | *Mean* | *St. Dev.* |
|---|---|---|---|---|---|---|---|
| How do you see the future of your farm? | 11.11 | 7.94 | 41.27 | 23.81 | 15.87 | *3.25* | *1.16* |

**Table 4**
Measures of technophobia and technophilia among farmers.

| | Strongly disagree (%) | Disagree (%) | Neither disagree nor agree (%) | Agree (%) | Strongly agree (%) | *Mean* | *St. Dev.* |
|---|---|---|---|---|---|---|---|
| I feel an irrational fear of new equipment or technology | 53.97 | 6.35 | 28.57 | 6.35 | 4.76 | *2.02* | *1.24* |
| I avoid the use of new equipment and technology | 46.03 | 12.70 | 15.87 | 11.11 | 14.29 | *2.35* | *1.50* |
| I feel uncomfortable when I use new equipment or technology | 36.51 | 17.46 | 17.46 | 17.46 | 11.11 | *2.49* | *1.42* |
| I am excited for new equipment or technology (R) | 17.46 | 33.33 | 19.05 | 9.52 | 20.63 | *2.83* | *1.40* |
| I am afraid of being left behind if I cannot use the latest equipment or technology (R) | 1.59 | 6.35 | 19.05 | 14.29 | 58.73 | *4.22* | *1.07* |
| I enjoy using new equipment or technology (R) | 22.22 | 26.98 | 19.05 | 7.94 | 23.81 | *2.84* | *1.48* |
| Cronbach's α = 0.787 | | | | | ***Total*** | ***2.79*** | ***0.95*** |

Note: R indicates that items have been reversely scaled in the analysis of the results.

**Table 5**
Perceived obstacles to the use of new equipment and technologies.

| | Strongly disagree (%) | Disagree (%) | Neither disagree nor agree (%) | Agree (%) | Strongly agree (%) | *Mean* | *St. Dev.* |
|---|---|---|---|---|---|---|---|
| They are too expensive | 15.87 | 3.17 | 30.16 | 19.05 | 31.75 | *3.48* | *1.39* |
| The internet connection is slow or absent | 46.03 | 12.70 | 28.57 | 9.52 | 3.17 | *2.11* | *1.19* |
| They are complex | 30.16 | 15.87 | 33.33 | 17.46 | 3.17 | *2.48* | *1.19* |
| They demand too much time | 22.22 | 14.29 | 25.40 | 23.81 | 14.29 | *2.94* | *1.37* |
| There are no clear benefits from their use | 50.79 | 12.70 | 25.40 | 4.76 | 6.35 | *2.03* | *1.24* |
| They are easy to break | 28.57 | 12.70 | 33.33 | 14.29 | 11.11 | *2.67* | *1.33* |
| They are not always compatible with each other | 17.46 | 11.11 | 55.56 | 11.11 | 4.76 | *2.75* | *1.03* |
| They distance me from the care of animals and crops | 44.44 | 9.52 | 23.81 | 4.76 | 17.46 | *2.41* | *1.52* |
| They do not offer the same precision as does manual labour | 50.79 | 11.11 | 17.46 | 9.52 | 11.11 | *2.19* | *1.44* |
| They are not adequate considering the farming practices used on the farm | 33.33 | 25.40 | 22.22 | 11.11 | 7.94 | *2.35* | *1.27* |
| Cronbach's α = 0.840 | | | | | ***Total*** | ***2.54*** | ***0.84*** |

**Table 6**
Motivations for the use of new equipment and technologies.

| | Strongly disagree (%) | Disagree (%) | Neither disagree nor agree (%) | Agree (%) | Strongly agree (%) | *Mean* | *St. Dev.* |
|---|---|---|---|---|---|---|---|
| They help monitor production | 4.76 | 1.59 | 26.98 | 23.81 | 42.86 | *3.98* | *1.10* |
| They help improve productivity | 9.52 | 4.76 | 33.33 | 25.40 | 26.98 | *3.56* | *1.22* |
| They help improve production quality | 6.35 | 0.00 | 36.51 | 30.16 | 26.98 | *3.71* | *1.07* |
| They help enhance production | 14.29 | 9.52 | 28.57 | 20.63 | 26.98 | *3.37* | *1.36* |
| They help fulfil production regulations (CAP and production specifications) | 9.52 | 4.76 | 19.05 | 34.92 | 31.75 | *3.75* | *1.23* |
| They reduce production costs | 26.98 | 23.81 | 30.16 | 11.11 | 7.94 | *2.49* | *1.23* |
| They help one make better farm management decisions | 11.11 | 11.11 | 23.81 | 31.75 | 22.22 | *3.43* | *1.27* |
| They allow one to improve the environmental impacts of the production process | 14.29 | 6.35 | 49.21 | 20.63 | 9.52 | *3.05* | *1.11* |
| They lighten the workload/improve work comfort | 20.63 | 11.11 | 25.40 | 22.22 | 20.63 | *3.11* | *1.42* |
| They help one manage breeding in a more conscious way | 9.52 | 3.17 | 20.63 | 36.51 | 30.16 | *3.75* | *1.20* |
| Cronbach's α = 0.874 | | | | | ***Total*** | ***3.42*** | ***0.84*** |

scores. We rejected the hypothesis of equality for all the factor mean scores, except for the technophobia construct in the comparison between the second and third clusters. Table 7 shows the average scores of the clusters, their respective sizes and the differences between clusters, while Fig. 3 graphically shows the mean scores of the clusters.

The first cluster (36.5% of the sample, $n = 23$), classified as *technophobes*, comprised the respondents who showed the highest level of technophobia (mean value of 3.72 out of 5.00). Compared to the other groups, these farmers perceived more obstacles (mean value = 3.37) and less benefits and motivation (mean value = 2.84) connected to the use of new technologies. The second cluster (42.9% of the sample, $n = 27$) showed a lower degree of technophobia (mean value = 2.54). Unlike the

**Table 7**
Average cluster scores.

| | Total sample (n = 63) | Cluster 1 (n = 23; 36.51%) | | Cluster 2 (n = 27; 42.86%) | | Cluster 3 (n = 13; 20.63%) | | F statistics (F-test) | |
|---|---|---|---|---|---|---|---|---|---|
| Technophobia | 2.79 | 3.72 | a | 2.54 | b | 1.67 | c | 65.747 | *** |
| Perceived obstacles | 2.54 | 3.37 | a | 2.06 | b | 2.08 | b | 40.909 | *** |
| Motivation to use | 3.42 | 2.84 | a | 3.38 | b | 4.52 | c | 35.255 | *** |
| *Cluster classification* | | *Technophobes* | | *Insecure technophiles* | | *Technophiles* | | | |

Significance levels: ***p < 0.001, **p < 0.010, and *p < 0.050.
[a, b, c] Indicate significantly different means using one-way ANOVA and the post hoc Dunnet T3 multiple comparison test (equal variances not assumed).

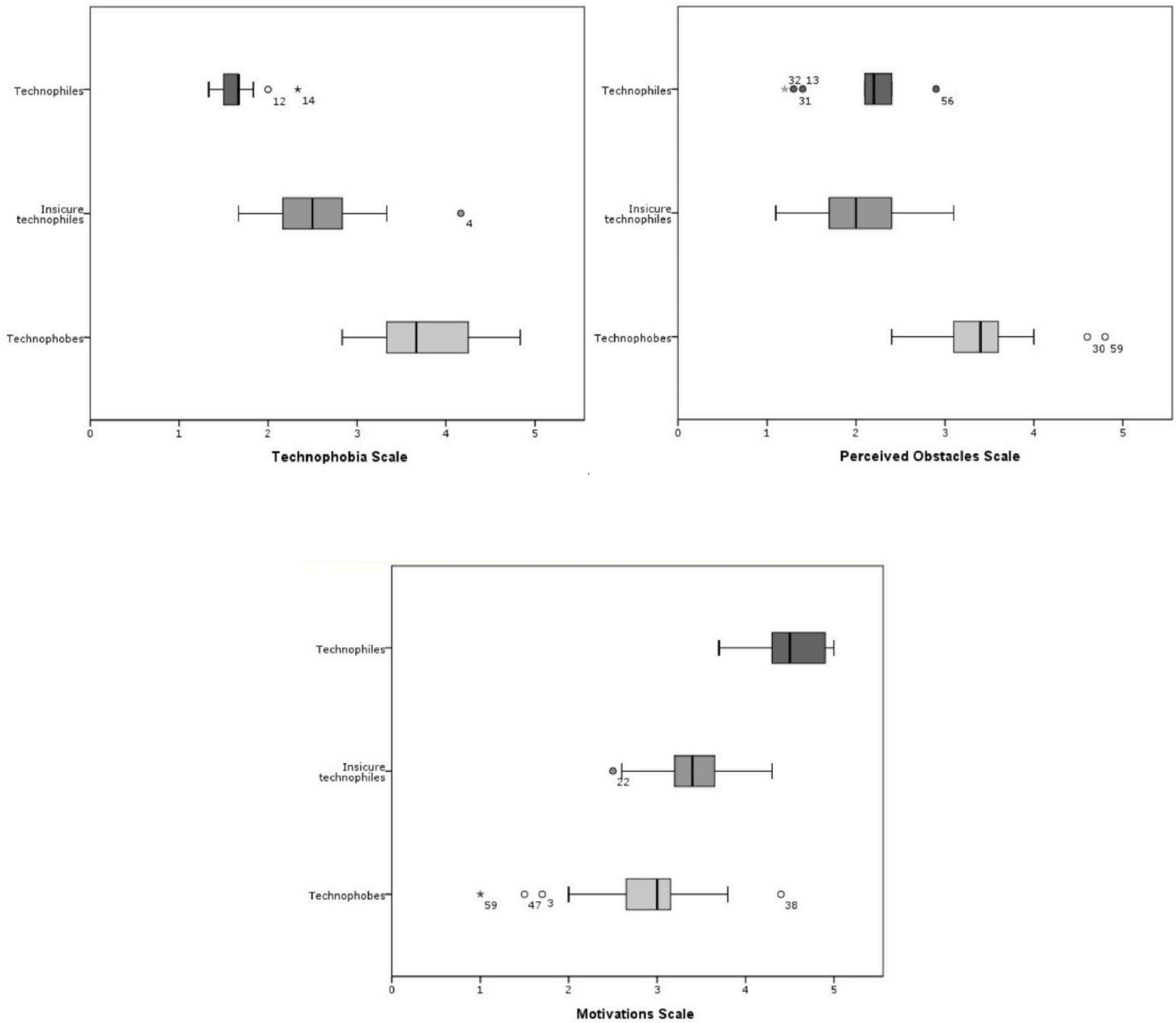


**Fig. 3.** Factor mean score differences between clusters.

first cluster, the farmers belonging to this group perceived fewer obstacles (mean value = 2.06) and had greater awareness of the benefits (mean value = 3.38) associated with the adoption of new equipment and technologies. Thus, this cluster was defined as *insecure technophiles*. Finally, the third cluster (20.6% of the sample, $n = 13$), described as *technophiles*, contained the farmers that reported the highest level of technophilia (mean value = 1.67). These respondents, compared to the first cluster, perceived fewer obstacles to the use of technologies (mean value = 2.08). Moreover, they recognized many positive benefits and motivations that incentivize the adoption of new technologies for breeding (mean value = 4.52).

Then, to further explore farm typologies, the three clusters were profiled using farmers' characteristics, such as gender, age, educational level, farm size, smartphone usage, and expectations for their professional futures. The differences between clusters were investigated using cross-tabulation with $\chi^2$ and Kruskal-Wallis statistics and one-way ANOVA *F* tests. Table 8 presents the profiles of the three identified clusters.

Statistically significant differences were found in terms of age ($p < 0.050$), educational level completed ($p < 0.010$), farm size ($p < 0.050$), expectations for the future ($p < 0.001$) and professional use of smartphones ($p < 0.001$). Gender was not found to differ significantly between the three identified clusters.

As reported in Table 8, farmers belonging to the *technophobe* cluster were more likely to be older (mean age = 53.0 years) and have a lower educational level (74.0% of them had completed only middle school). Moreover, they were more likely to own a smaller farm (45 lactating cows on average). With respect to smartphone usage, the respondents in this cluster had the lowest frequency of use of smartphones for professional duties (mean value of 1.67 out of 5). Furthermore, compared to the other clusters, adverse technophobe farmers were significantly more pessimistic concerning the future of their farms, with 21.7% of them being pessimistic or very pessimistic. In contrast to the first cluster, the intermediate group of *insecure technophiles* contained significantly younger and better-educated farmers. The respondents of this group showed a significantly higher frequency of smartphone use for professional purposes (mean value of 2.91 out of 5). Furthermore, generally, these farmers were more optimistic (44.4% optimistic or very optimistic) concerning the future of their activities. Finally, respondents belonging to the *technophile* cluster had the highest educational level (15.4% of them had a master's degree) and ran larger farms (103 lactating cows on average). Moreover, as expected, the respondents of this group used smartphones for professional purposes significantly more than the average. Overall, enthusiastic technophiles were the respondent group showing the most positive attitudes towards the futures of their farms (76.9% were optimistic, of which 53.8% were very optimist); no enthusiastic technophile farmer declared that he or she was pessimistic about the future.

**Table 8**
Cluster profiles based on the characteristics of farmers and farms.

| | Cluster 1 | Cluster 2 | Cluster 3 | p-value | | |
|---|---|---|---|---|---|---|
| | Technophobes | Insecure technophiles | Technophiles | | | |
| | *(%, n = 23)* | *(%, n = 27)* | *(%, n = 13)* | ($\chi$2-test) | (Kruskal-Wallis test) | (ANOVA *F*-test) |
| *Gender* | | | | 0.200 | | |
| Male | 78.26 | 85.19 | 100.00 | | | |
| Female | 21.74 | 14.81 | 0.00 | | | |
| *Age* | | | | | | 4.588 * |
| Mean interviewed age (years) (*St. Dev.*) | 53.00 (*13.15*)[a] | 43.15 (*9.93*)[b] | 45.46 (*12.39*)[b] | | | |
| *Educational level completed* | | | | | 0.009 ** | |
| Elementary school | 13.04 | 0.00 | 0.00 | | | |
| Middle school | 60.87 | 40.74 | 30.77 | | | |
| High school | 21.74 | 55.56 | 53.85 | | | |
| University bachelor's degree | 4.35 | 3.70 | 0.00 | | | |
| University master's degree | 0.00 | 0.00 | 15.38 | | | |
| *Size of farm* | | | | | | 4.228 * |
| Mean number of cows (*St. Dev.*) | 45.52 (*31.52*)[a] | 59.41 (*43.16*)[a] | 103.00 (*103.92*)[b] | | | |
| *Professional use of a smartphone* | | | | | | 20.517 *** |
| Frequency mean (*St. Dev.*) | 1.67 (*0.80*)[a] | 2.91 (*0.86*)[b] | 3.26 (*0.78*)[b] | | | |
| *Expectations for the future of the farm* | | | | | 0.001 *** | |
| Very pessimistic | 17.39 | 11.11 | 0.00 | | | |
| Pessimistic | 4.35 | 14.81 | 0.00 | | | |
| Neither pessimistic nor optimistic | 65.22 | 29.63 | 23.08 | | | |
| Optimistic | 4.35 | 40.74 | 23.08 | | | |
| Very optimistic | 8.70 | 3.70 | 53.85 | | | |

Significance levels: ***$p < 0.001$, **$p < 0.010$, and *$p < 0.050$.
[a, b] Indicate significantly different means using one-way ANOVA and the post hoc Dunnet T3 multiple comparison test (equal variances not assumed).

## 5. Discussion

The results showed that attitudes towards new technologies are affected by age, educational level, farm size, actual smartphone usage for professional duties and optimistic expectations for the future of the farm. Educational level, farm size, smartphone usage and expectations for the future increased significantly across clusters from the first cluster of technophobes to the third cluster of technophiles. Moreover, age significantly decreased from the first cluster to the other clusters. Therefore, our findings suggest that older farmers with lower educational levels, smaller farms, less frequent smartphone usage for professional duties, and more pessimistic feelings regarding the future of their farm are less willing to adopt new technologies. These farmers do not have the knowledge and confidence to understand the benefits related to the use of technologies for breeding. To overcome these issues, considering that "information is the key to the diffusion of innovations" (Tey and Brindal, 2012), new forms of presentation and learning may be developed by service providers and policy makers to address the needs of these adverse technophobe farmers, who constitute a relevant part of the population. This innovation process is of great importance since technophilia, or the propensity to use new technologies, plays a fundamental role in the sustainable development of mountain farming and breeding.

Although our results cannot be generalized to all mountain areas and to the whole mountain area itself, we found several elements that are in line with the previous literature (Khanna, 2001; Adrian et al., 2005; Pierpaoli et al., 2013; Avolio et al., 2014; Caffaro and Cavallo, 2019). More specifically, in terms of age, our findings corroborate previous evidence showing the existence of a negative relationship between age and the adoption of new technologies, probably because older farmers have shorter career horizons than do younger farmers and, therefore, are less motivated to innovate (Roberts et al., 2004; Larson et al., 2008; Tey and Brindal, 2012). With reference to educational level, the results are consistent with the previous literature reporting that less educated farmers are less confident and less inclined to use new technologies (Adrian et al., 2005; Tey and Brindal, 2012; Pierpaoli et al., 2013; Caffaro and Cavallo, 2019). Considering farm size, we found that technophobe farmers have smaller herds, as reported in the literature, probably because smaller farms do not create adequate economies of scale and incentives for the adoption of new technologies for farm management (Caffaro and Cavallo, 2019). The owners of larger farms are more able to absorb the associated costs and risks. With respect to smartphone usage, technophobe farmers had the lowest frequency of use of smartphones for professional duties, meaning that farmers who are less confident in using technological devices have fewer technological skills and are more likely to have a negative attitude towards new technologies and be more reluctant to innovate (Pierpaoli et al., 2013).

Although our findings related to age, educational level and farm size have been analysed in previous papers (Khanna, 2001; Adrian et al., 2005; Pierpaoli et al., 2013; Avolio et al., 2014; Caffaro and Cavallo, 2019), some novelties of our study are worth emphasizing. First, we focus on a sample of mountain dairy farmers. Second, we propose a clustering analysis of the farmers based on three attitudinal determinants: (1) technophobia and technophilia, (2) perceived obstacles, and (3) motivations to use. To date, this approach has not been applied to farming system analysis, even if understanding the underlying factors that affect the adoption of technologies is imperative to allow policy makers to develop more effective and targeted policies.

## 6. Concluding remarks

The EU has recognized mountainous areas as the most disadvantaged areas for agriculture. Nonetheless, agricultural activities play a fundamental role in the maintenance of mountainous landscapes and environments and in the economic support of local communities. Considering the structural problems and importance of mountain farming, special support programmes have been developed in the CAP, and the current public policies increasingly support the adoption of smart agriculture techniques. Despite the incentives and advantages related to the adoption of such innovation practices, their diffusion is still limited, especially in the case of ICTs.

This study has demonstrated the existence of different farmer profiles, considering their attitudes towards the adoption of technological devices in a sample of Italian mountain dairy farmers. Considering technophobia and technophilia, the perceived obstacles and the motivations to use new technologies, as well as by means of cluster analysis, three different classes of farmers were identified: *technophobes*, *insecure technophiles* and *technophiles*. Farmers more prone to adopting technology are those who are younger and more educated and have a larger herd and optimistic expectations for the future. The empirical results show at least two interesting pieces of evidence for policy makers and stakeholders. First, they prove that there are heterogeneous attitudes towards technologies among mountainous farmers, which suggests that the poor success of public policies of smart farming may be due to a top-down intervention that while, on the one hand, works for the group of enthusiastic farmers, on the other hand, it is not adequate for neophobic farmers. Second, the present application demonstrates that clustering techniques can be applied to understand and measure the differences between farmers and suggests that they can be used as *ex ante* analytical methods to estimate the impact of different policy scenarios.

Finally, some limitations of the study are worth mentioning. While the questionnaires allowed us to collect interesting primary data, it must also be underlined that to avoid respondents' fatigue and therefore increase the survey response rate, we kept the questionnaires short and focused. This implies that some data may have not been collected, leading to a possible omitted variable bias. Another limitation is that the implied method only provides us with a description of the relationships among the investigated variables but does not allow us to explain their causal relations. Furthermore, compared to the northern Italian farming system, the farms in the case study exhibit almost homogenous characteristics. For example, they are homogeneously spatially distributed in the overall area and are all dairy farms performing extensive farming practices, combining stable valley meadows in the winter and high-altitude pastures in the summer. For this reason, it is not possible to adopt some segmentation variables that may better explain the farmers' propensity to innovate (i.e., farms' spatial distribution, marginality, access to technical advice, and farming system characteristics). For these reasons, we suggest a further investigation into the factors affecting farmers' adoption of new technologies. Future research can replicate this study in other areas of the region with other territorial characteristics (e.g., flat areas) or with other farming systems.

## 7. Author statement

Conceptualization, M.E.M., E.D., R.F. and A.G.; methodology, M.E. M; software, M.E.M.; validation, M.E.M., E.D., R.F., A.G.; formal analysis, M.E.M. and E.D.; investigation, M.E.M. and E.D.; data curation, M. E.M., E.D., R.F.; writing—original draft preparation, M.E.M.; writing—review and editing, M.E.M., E.D., R.F., A.G.; funding acquisition, A.G. All authors have read and agreed to the published version of the manuscript.

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