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A Future for Mountain Terraces: Experiences from Mediterranean Wineries

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Agriculture in mountain areas is typically practiced on terraces. This form of farming is facing significant challenges across the globe related to high production costs, land abandonment, and rural depopulation. The aim of this study was to explore the viability and prospects of mountain farming using the wineries in the terraced mountains of Cyprus as a case study. A semistructured questionnaire was developed, and 11 family wineries were selected and surveyed. The study found that mountain winery owners envision a future where abandoned mountain plots are productively utilized. The survey showed that mountain wineries are financially viable agribusinesses and share a common desire for sustaining and enhancing the quality of the wine produced to support their long-term success. The revitalization of mountain farming can potentially lead to the development of other rural enterprises and create employment opportunities to sustain young families in the mountains. Investments in drystone terraces were found to be costly, especially for wineries that were located at higher elevations (€ 150/m or US$ 171.30/m) compared to those on gentler slopes and lower elevations (€ 20/m or US$ 22.84/m). Nevertheless, the majority of winery owners recognized the provision of ecosystem services by drystone terraces, such as the reduction of soil erosion and the formation of a unique mountain terroir that enables the production of niche wines. Although the survey found that subsidies for terrace construction and maintenance are a small part of the revenue for these wineries, policy measures can become more targeted, effective, and equitable by considering the actual costs of terracing, as determined by site-specific characteristics such as elevation, slope, and geology.

Keywords: *mountain agriculture; grape; wine; cultural landscape; rural development.*

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Introduction

Agriculture in mountain areas across the globe is typically practiced by family farmers (Wymann von Dach et al 2013). Although there are many diverse features of mountain farming, owing to the different elevations, climate regimes, and landscape features, mountain agricultural systems share many common characteristics. For instance, mountain farms utilize marginal lands that would otherwise remain uncultivated, and they are often overlooked in national accounting systems due to their relatively smaller contribution in terms of product quantity (Tarolli et al 2019). Mountain farmers are often motivated by social and cultural factors. Although these incentives do not generate income directly, they contribute to the maintenance of mountain landscapes, which provide indispensable ecosystem services, sustain the natural production base, and support development beyond rural mountain areas (Bernues et al 2014; Schirpke et al 2016; Cicinelli et al 2021). Mountain farmers are also custodians of place identity, cultural values, and indigenous knowledge, which is exemplified by the terraced landscapes found in all major mountain regions of the world.

The main purpose of terraces has been the cultivation of land in high and steep areas, with farmers devoting substantial amounts of hard work to transpose mountain slopes into cultivable land suitable for production. The terraced fields control soil erosion through soil and water retention and provide microclimatic adjustments that create suitable conditions for farming (Maetens et al 2012). For centuries, agricultural terraced areas worldwide have been growing. The most common type is bench terraces, which are often supported by drystone walls and are now characterized as land with "high nature value" (Bignal and McCracken 2000; Keenleyside et al 2014). Terraces are part of traditional cultural landscapes; that is, they have distinct structures and elements of high significance for sustainable land management practices, as well as for natural (eg biodiversity), cultural, and aesthetic values (Antrop 1997; Harrop 2007).

In Europe, and more evidently in the Mediterranean region, the cultivation of important permanent crops such as vines was a powerful push toward terracing (Bonardi 2019). Despite the important role that terraces have played in sustaining mountain families, this trend began to change in the mid-20th century (MacDonald et al 2000). The greater

socioeconomic opportunities in urban centers compared to those in the mountain farmlands induced younger generations to migrate, and consequently many terraced areas were gradually abandoned. The development trends that followed contributed to the loss of cultural values, in addition to the loss of valuable farmland that had been shaped for centuries in European and Mediterranean mountain areas (MacDonald et al 2000).

Numerous studies have been devoted to documenting the adverse effects of terrace abandonment in countries such as Spain (Arnaez et al 2011; Rodrigo-Comino et al 2019), France (Van Eetvelde and Antrop 2004), Italy (Tarolli et al 2014), Greece (Koulouri and Giourga 2007; Tzanopoulos et al 2011), Cyprus (Camera et al 2018; Djuma et al 2020), and Malta (Cyffka and Bock 2008), and also in central Europe (Lieskovský et al 2015). The majority of these studies reported the collapse of drystone terraces and increasing risk of soil erosion, which progressively leads to land degradation and desertification. However, several studies have also noted the reduced soil erodibility of abandoned terraced slopes following their colonization by natural vegetation (eg Djuma et al 2017). Apart from the changes in the socioeconomic status of mountain communities, the high labor effort and the cost of the maintenance and cultivation of terraces are often cited as the main reasons for their abandonment (Zoumides et al 2017). According to Louwagie et al (2009), research on the economics of terraces is limited to a few studies that have been conducted in Europe (eg case studies in Italian terraced vineyards and olive groves by Torquati et al 2015, 2019). Louwagie et al (2009) also pointed out that terraces are located in geomorphologically heterogeneous areas, and additional factors should be taken into account when assessing their economic viability, such as the ecosystem benefits and the perception of farmers.

Following the recognition of the cultural and environmental consequences of abandonment, the past 2 decades have seen a renewed interest in the protection and rehabilitation of agricultural mountain terraces (Tarolli 2018). In terms of rural policy, this recognition is evident in, for instance, the European Union regulation for common organization and support programs for the wine market of 2008 (European Commission Regulation No. 555/2008 [European Commission 2008]), as well as in the more recent establishment of ecological focus areas within the Common Agricultural Policy (CAP) and the Farm to Fork Strategy (European Commission 2020), where drystone terraces are considered to be landscape features that safeguard and improve biodiversity. While terracing is one of the more effective techniques for reducing soil loss and conserving water (Maetens et al 2012), there are no relevant findings on the long-term environmental effectiveness of greening measures, such as terraces, ditches, and ponds (Alliance Environnement 2017). Investigations into the unique characteristics, potential successes, and future prospects of mountain terraces and family agribusinesses are also lacking from the literature.

The aim of this study was to explore the viability, strategies, and visions of mountain wineries in terraced environments. The wine sector is multifaceted; on the one hand, terraced vineyards form a distinct landscape category within the wider framework of agricultural terraces (Bonardi 2019), and, on the other hand, wine is an agricultural product associated with its place of origin, and its production is responsive to market changes toward quality (Torquati et al 2015). The study followed a bottom-up approach, with the analysis being based on surveys of winery operators in mountain communities of Cyprus. The specific objectives of the study were (1) to identify the structural characteristics of mountain vineyards, (2) to document the motivations and costs associated with the establishment and maintenance of drystone terraces, (3) to analyze the economic performance of mountain wineries, and (4) to investigate the winery operators' parameters of success and perspectives for the future of mountain agriculture.

Methodology

Study area

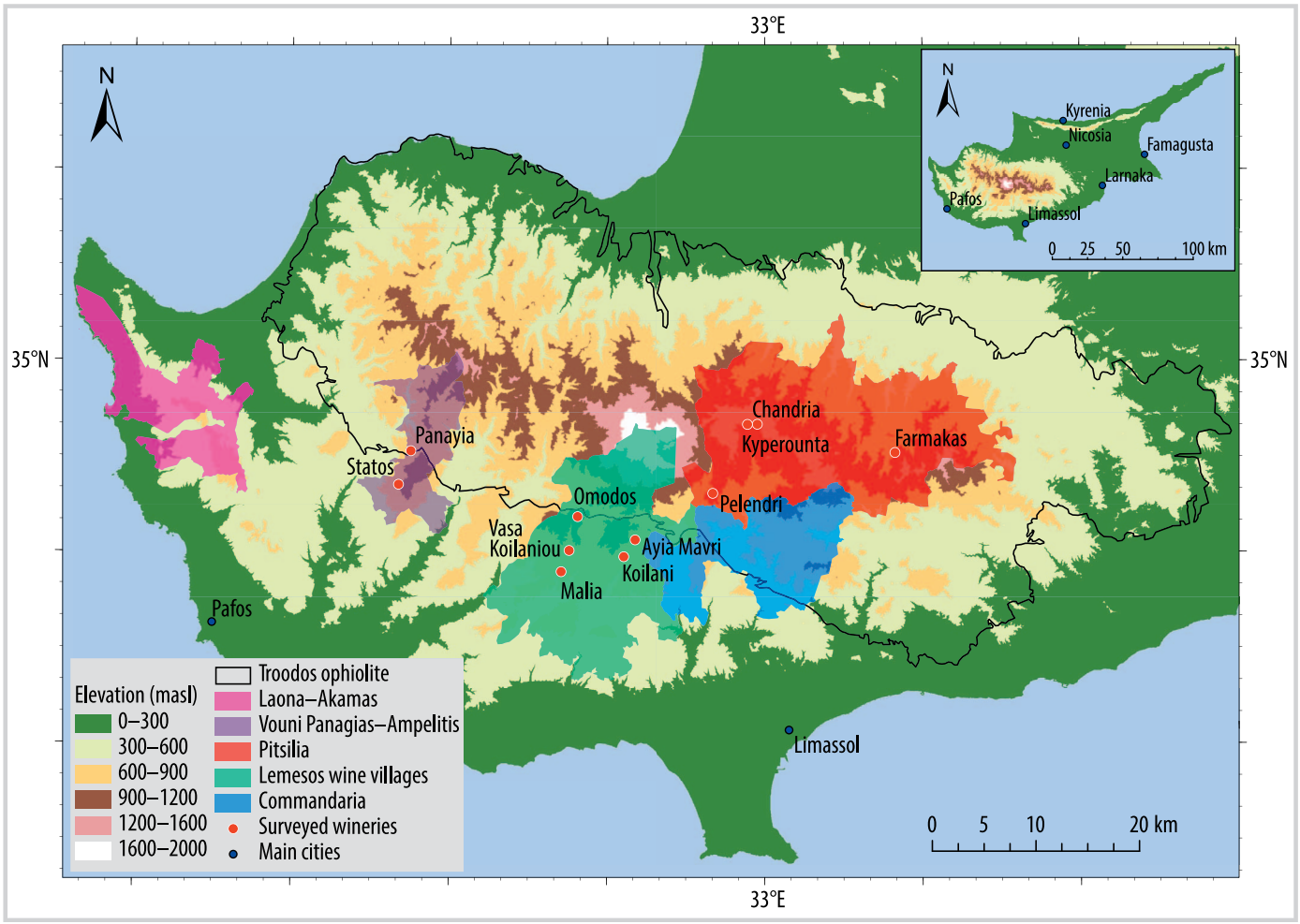
The island of Cyprus is located in the eastern Mediterranean. The Troodos Mountains that dominate the center of the island comprise an ophiolite complex, which is surrounded by sedimentary cover. The Troodos Ophiolite Complex, with its highest peak at 1952 masl, has a mean slope gradient of 31% and covers 40% (Zoumides et al 2017) of the island's area (Figure 1). Average annual rainfall ranges between 500 mm in the foothills to 1100 mm near the peak at 1950 masl (Camera et al 2014).

The study focused on vineyards in the Troodos Mountains, which are typically found on drystone terraces (Figure 2). At higher elevations with steep slopes (eg 20–40% gradient), terraces are constructed by cutting and filling, and terrace benches tend to be narrow (1–3 m) to moderately wide (3–6 m) (Zoumides et al 2017). At lower elevations, terraces can be wider, for example, with more than 20 m bench width. The share of the terraced land and the importance of grapes increase progressively with elevation. Based on data from the Cyprus Agricultural Payments Organisation, in 2016, grapes accounted for more than 40% of the total crop land utilization in communities at elevations above 600 m (Figure 3). Abandonment of agricultural terraces is pervasive across the mountain region; over the past 2 decades, 20% of agricultural land in communities above 600 m has been abandoned (Cystat 2014).

Despite these decreasing trends, grapes remain an important mountain crop. More recently, grape growers and winemakers have shifted the production from quantity to quality, following the wider market direction for better quality wine products. Significant efforts were also placed on improving indigenous grape cultivars such as *Mavro*, an ancient red variety that is well adapted to mountain slopes, and *Xynisteri*, a white variety. By 2009, these 2 varieties covered 66% of the wine grape cultivated area and constituted 53% of the wine production (Cystat 2011).

Regarding quality parameters, the national legal framework is aligned with European Union (EU) regulations. For instance, among other provisions, EU Regulation No. 1308/2013 stipulates suitable grape varieties, wine-growing methods, and yield limits per hectare, as well as ensuring that grape production and wine making are carried out in a specific region. Based on the EU (eg EC regulation No. 607/2009 [European Commission 2009]) and the equivalent national regulations (ie Administrative Act 48/2016), wines produced in Cyprus are currently classified and labeled in the following categories: wine, local wine, and wine of protected designation of origin. The latter is the most

FIGURE 1 Wine regions with protected designation of origin and surveyed mountain wineries.



prestigious category and specifies the wine-producing regions of Cyprus (Table 1; Figure 1). Today, according to the official registry of the Cyprus Department of Agriculture, there are 115 local enterprises that are licensed to commerce or produce wine products. The list includes 4 big companies, which, apart from utilizing grapes from various farmers, have also developed their own vineyards. Fifty of the listed enterprises are small, regional wineries, while the remaining 61 enterprises focus on trading wine products.

Survey design, sample selection, and analysis

A semistructured questionnaire was developed to collect primary information and insights regarding the wineries' structure, strategies, and farming practices on terraces and conducted through face-to-face interviews with winery owners. The questionnaire consisted of 9 sections, with ranking, scoring, and open questions. The questionnaire covered 4 main topics: (1) winery characteristics and farming practices, including year of establishment, managed area (owned or rented), employment, and grape varieties grown, (2) drystone terrace construction and maintenance costs, (3) production output, including the cost, revenues, and factors determining the success of wineries, and (4) concerns, visions, and prospects of mountain wineries.

The selection of the wineries for the survey followed these criteria and steps:

- Family-based: The starting point of the sample selection was the list of the 50 regional and predominantly family-based wineries reported in the official registry. Some wineries are owned by the 4 big companies but operate as an estate (or family-based) winery (eg the winery located in Malia community).
- Elevation: The focus of the study was on mountain terraced vineyards, so the elevation threshold was set to wineries located at 600 masl and above, in line with the protected designation of origin regulation (Regulatory Administrative Act 48/2016). This resulted in a subset of 32 mountain wineries located in 4 of the 5 wine regions. The Commandaria region was not included because it did not have wineries above 600 m.
- Regional coverage and active market presence: Based on expert knowledge, 14 wineries were selected, representing at least 28% of the mountain wineries in each region.

The questionnaire (see Appendix S1, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-21-00031.1.S1) was first sent to the selected wineries via email, followed by phone communications to confirm their interest and arrange the face-to-face interviews. At this stage, the only eligible winery in the Laona–Akamas region noted that its vineyards are on a plateau and not on terraces, so it was excluded from the sample. In addition, one of the selected

FIGURE 2 Vine terraces in Troodos Mountains. Red boxes on Google Earth images (right) show the photographed terraces (left) in (A) Pelendri, (B) Kyperounta, and (C) Panayia mountain vineyards. (Photos by Christos Zoumides)

wineries indicated that it did not own any vineyards, and all the wine was produced using grapes from different farmers, while another winery refused to participate. Thus, the final sample consisted of 11 wineries, still maintaining a minimum of 28% of the wineries in the 3 main wine regions. These winery operators were interviewed in the summer of 2017. A follow-up survey was conducted in 2020 to verify and gather further data on the economics of the wineries.

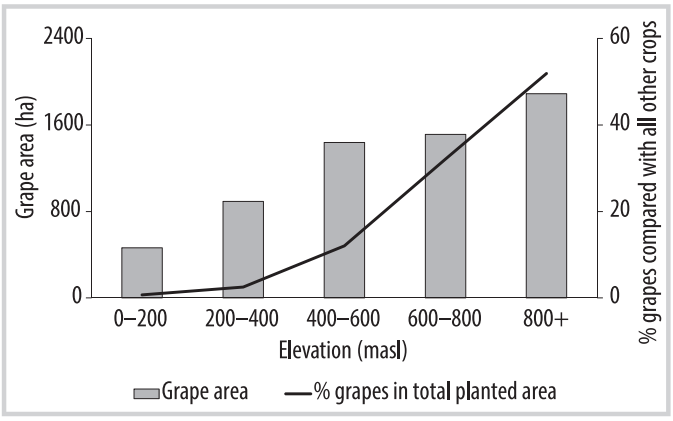
The information collected from the interviews was coded and categorized in tabular format. In line with the objectives of the study, the analysis followed a descriptive and interpretive approach (Elliott and Timulak 2005). The responses to the scoring and ranking questions from all wineries were averaged, and the mean values were used for interpretation. To assess the profitability of mountain wineries, we computed the standard gross margin, in both absolute (€) and per hectare (€/ha) terms, which is the difference between the revenues of each winery and variable production cost (including terrace maintenance), based on the definition outlined by the European Commission Decision (EEC) No. 377/1985. Information on the geology at the wineries' locations was obtained from the geological map of Cyprus (Geological Survey Department of Cyprus 2019).

Results and discussion

Winery characteristics and farming practices

The surveyed Cypriot mountain wineries are structurally different from each other, and, although they share common

FIGURE 3 Area cultivated with grapes by elevation, and share compared to all other crops in 2016, based on data obtained from the Cyprus Agricultural Payments Organisation.



 https://doi.org/10.1659/MRD-JOURNAL-D-21-00031.1

TABLE 1 Wine regions with protected designation of origin status in Cyprus.

Characteristic	Wine-producing region of Cyprus				
	Laona–Akamas	Vouni Panagias–Ampelitis	Pitsilia	Lemesos wine villages (Krasochoria)	Commandaria
Location	Northwestern part of Cyprus	Southwestern slopes of Troodos Mountains	Eastern slopes of Troodos Mountains	Southern slopes of Troodos Mountains	Southern slopes of Troodos Mountains
Elevation range (masl)	400–600	600–1145	800–1400	500–1100	500–900
Dominant geological formation	Calcareous	Diabase	Gabbro and diabase	Calcareous	Ophiolite formations/ calcareous
No. of communities	6	4	32	22	14
Grape area[a)] (ha)	650	600	1282	1653	538
Grape production[a)] (tons)	2602	2249	4848	6891	2141

[a)] Grape area and production refer to the period of 2016–2018 (average values), based on Department of Agriculture data.

entrepreneurial goals, as is later discussed, each case is unique. An overview of the winery characteristics is presented in Table 2, which lists the surveyed wineries by elevation. The highest surveyed winery was located at 1216 masl, and the lowest surveyed winery was located at 674 masl. An interesting characteristic that indicates the diversity of wine-growing regions and conditions in Cyprus is the geological formations where mountain vineyards are located. The higher vineyards are generally on steeper slopes, and the predominant geology consists of gabbro, followed by the less permeable rocks of the diabase formation, both of which are part of the Troodos Ophiolite Complex (Constantinou and Panayides 2013). At lower elevations and slope gradients, vineyards are found on autochthonous sedimentary rocks and the calcareous Pachna Formation and Lefkara Formation. Geology and various other territory values and physical environmental factors, such as landscape characteristics, soil, and climate, are ingredients of the terroir concept, which determines to a large extent the style and quality of wines produced (van Leeuwen 2010).

With the exception of the winery located in Malia, all other mountain wineries are newly established enterprises that started operating in the last 3 decades (Table 2). This characteristic is indicative of the peculiarities of mountain rural development and the commercialization of wine production in Cyprus; while the island has a long wine production history, small, family-based wineries are a recent development. Seven out of 11 winery owners are above the age of 50, but they have identified a successor within the family. As family-based enterprises, the investment of the sampled wineries is driven by, inter alia, the creation of prospects and financially sustainable rural businesses that can be inherited by their children, some of which are already working in the family business following their studies in agronomy or enology.

Another important structural characteristic is the area managed by the mountain wineries, that is, the combined owned and rented area. The area ranged from 3 to 48.5 ha and averaged 18.5 ha. Also, 8 out of the 11 wineries were planning to expand the vineyard area under their management in the next decade, aiming to become more self-sufficient in wine grape production and to have better control of the growing conditions (Table 2). Comparatively, the average vineyard area per holding in the European Union in 2015 was 1.3 ha (Eurostat 2017); France had by far the highest average area per holdings with 10.5 ha, while Romania, Malta, Croatia, Cyprus, and Greece ranked among the countries with lowest vineyard areas per holding, with 0.5 ha or less. This finding indicates that the operation of wineries entails the consolidation of farm holdings and the expansion of managed vineyards; even the smallest mountain winery in this study's sample was managing 4 times more land than the average vineyard holding in Cyprus and almost twice the European average.

In terms of employment, the average number of full-time personnel (including grape and wine production) at mountain wineries in Cyprus was 11.5 people, ranging from 6 to 24 full-time employees; these numbers included family members. Also, the wineries employed on a part-time basis 10.3 people for 75 days, on average, per year. Part-time employment is primarily associated with grape harvesting, which takes place between June and November.

Regarding vineyard management, the average plant density was found to be 3700 plants/ha, ranging from 2500 up to 5000 plants/ha. The winery owners explained that spacing depends on grape variety. Also, traditionally, vineyards tend to be more spaced at lower elevation, while the more densely planted vineyards are found at higher elevations. This is also related to the higher rainfall and the limited cultivable land on the steeper mountain slopes at higher elevations. In terms of irrigation, 4 wineries relied exclusively on rain for grape production, while in the remaining 7 wineries, the share of irrigated land ranged from 4 to 100%. These numbers refer to the vineyard areas that are equipped with irrigation systems and do not mean that wineries are fully irrigating these areas. The winery owners explained that they provide irrigation on a supplementary basis during critical crop growth periods. For instance, the winery owner in Koilani mentioned that he applies controlled irrigation volumes to ensure yields of good-quality grapes for wine making. In their in-depth review of the international literature on climate change

TABLE 2 Characteristics of surveyed mountain wineries. (Table extended on next page.)

Characteristic	Winery				
	Chandria	Kyperounta	Farmakas	Pelendri	Statos–Agios Photios
Elevation (masl)	1216	1123	959	902	831
Slope (%)	39	30	43	33	25
Geological formation	Gabbro	Gabbro	Diabase	Gabbro	Calcareous
Wine region	Pitsilia	Pitsilia	Pitsilia	Pitsilia	VPA
Age classes of owner	30–39	40–49	>65	60–65	60–65
Establishment year	2013	1998	2015	1988	2007
Agricultural education	Yes	Yes	Yes	No	No
Full-time employees	8	24	6	13	10
Part-time employees (no. days/y)	4 (90)	2 (60)	3 (120)	20 (25)	14 (90)
Owned land (ha)	7	11	3.5	5	6.1
Rented land (ha)	8	5	19	3	13
Irrigated land (%)	55	53	4	100	0
Average plant density (vines/ha)	5000	3850	4500	4000	2500
Local/ international grape varieties	4/6	1/3	2/0	5/7	4/2
Change in vineyard area in the past decade (ha)	2.2	10	22.5	9	3.5
Expansion plans in the next 10 years (ha)	1	23	20	15	10

Note: VPA, Vouni Panagias–Ampelitis.

effects and adaptation strategies in the wine sector, Sacchelli et al (2016) reported that irrigation is an emerging topic of significance in recent studies on climate vulnerability.

The grape varieties that are grown on the mountain terraces of the wineries is another interesting characteristic (see Table S1, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-21-00031.1.S1). The first impression from this matrix is the wide range and mixture of local and international varieties. Banilas et al (2009) noted that the genetic diversity of the indigenous Cypriot germplasm requires further attention to be conserved and productively exploited. In essence, each winery seeks to produce niche wines that will be distinct, recognizable, and competitive in the market. The choice of the varieties grown depends on the strategy, the philosophy, and the range of wines that each winery wants to produce. For instance, the wineries located in Panayia and Farmakas were only producing wines from local varieties, as they considered them to be better suited and more resilient to the semiarid conditions of Cyprus. Other wineries, such as those located in Chandria, Pelendri, and Koilani, had a balanced mixture of local and international varieties, while the winery in Ayia Mavri, which specializes in dessert wines, was the only surveyed winery that grew the local Muscat variety. Another factor that affects the variety choice is enological developments and trends. Eight of the winery owners mentioned that, apart from the well-developed local varieties of *Xynisteri*, *Maratheftiko*, and *Mavro*, all other local varieties have, until recently, not been explored in terms of their potential to produce good-quality wine. Gradually, however, more and more wineries are investing and experimenting with local varieties such as *Yiannoudi*, which was cultivated by 5 out of the 11 surveyed wineries.

Terrace construction and maintenance—motivations and costs

The characteristics of the terraced fields and the costs of terrace construction and maintenance at the surveyed wineries are summarized in Table 3. Five out of 11 wineries had all their vineyards (100%) on well-maintained drystone terraces, while at the remaining 6 wineries, the share of well-maintained terraced fields ranged from 5% in Farmakas to 70% in Malia. The small share of terrace maintenance in Farmakas is attributed to the recent establishment of the winery. Although vineyards are on old terraces, few were in a well-maintained state; the owner mentioned that maintaining the collapsed drystone walls is a laborious and costly activity. In other cases, such as the winery in Koilani, the owner mentioned that he prefers fields that are relatively flat or with gentle slopes for his vineyards, and he uses terraces only when it is necessary. Also, 70% of the vineyards in the Malia winery were on terraces, but instead of drystone walls, they were vegetated to ensure stability. Vegetation cover to reinforce terrace stability requires careful selection of drought-tolerant plants (Novara et al 2011; Lieskovský and Kenderessy 2014; Rodrigo-Comino et al 2019). Vegetating the terrace façade is, however, not common in the mountain vineyards in Cyprus.

Regarding terrace dimensions, there was a wide range of terrace sizes. Terrace height ranged from 1.0 m to 3.5 m, while for the width, the range was even larger, from narrow

TABLE 2 Extended. (First part of Table 2 on previous page.)

Characteristic	Winery					
	Ayia Mavri	Koilani	Omodos	Panayia	Vasa Koilaniou	Malia
Elevation (masl)	820	820	817	814	805	674
Slope (%)	28	28	26	41	25	23
Geological formation	Calcareous	Calcareous	Calcareous	Diabase	Calcareous	Calcareous
Wine region	Krasochoria	Krasochoria	Krasochoria	VPA	Krasochoria	Krasochoria
Age classes of owner	>65	40–49	50–59	60–65	40–49	50–59
Establishment year	1986	1998	2010	1987	1993	1927
Agricultural education	No	Yes	No	Yes	No	Yes
Full-time employees	13	10	6	6	13	22
Part-time employees (no. days/y)	10 (60)	2 (60)	6 (30)	25 (180)	7 (30)	20 (75)
Owned land (ha)	3	15.4	12	10.5	7.5	0
Rented land (ha)	0	6	15	5	0	48.5
Irrigated land (%)	0	44	0	0	70	100
Average plant density (vines/ha)	3750	3500	2500	4000	4500	2700
Local/ international grape varieties	4/3	4/6	6/4	7/0	1/5	3/4
Change in vineyard area in the past decade (ha)	1	6	27	30	1	0
Expansion plans in the next 10 years (ha)	0	15	0	20	1	0

2 m terrace benches at Pelendri to 80 m wide at Vasa Koilaniou. The dimensions of terraces (including their average length, measured as running meter of walls per hectare) are additional characteristics that indicate the diversity and complexity of mountain terraced systems. Although the principles of terrace construction were similar across the surveyed vineyards, their dimensions were shaped by site-specific geomorphological characteristics. This complexity was noted by the respondents to the questionnaire. In other words, there was no homogeneity between mountain terraced fields, even between those of the same winery, which made it challenging for respondents to provide this information. Thus, the terrace dimensions should be treated as rough estimations for each case.

The average total establishment cost, including both the labor and the material costs, was found to be € 75/m (US$ 85.65/m) of drystone wall. This average excludes the winery at Malia, where the cost refers to the planting of the terrace façade for stability. Similar to the terrace dimensions, the establishment cost is also subject to site-specific characteristics, and it varied widely between the surveyed wineries, from € 20/m (US$ 22.84/m) at Ayia Mavri to € 180/m (US$ 205.56/m) at Vasa Koilaniou. The establishment cost was generally higher for vineyards that were located on steeper slopes, where the predominant rocks consist of gabbro, than for those on calcareous geological formations. Besides the steeper slopes, the hardness of gabbro and diabase rocks requires more effort and time for wall construction, which explains the higher cost. The case of the winery located at Vasa Koilaniou is an exception to this rule; although the vineyards are on calcareous formations, it had the highest terrace establishment cost within the sample. As explained by the winery owner, this was due to the lack of good raw materials for wall construction, so a large share of the total establishment cost came from to purchasing stone. Regarding the maintenance of drystone terrace walls, the average annual cost was € 3058/ha (US$ 3492.24/ha), based on the responses of 5 out of the 11 surveyed wineries (Table 3).

Currently, there are 2 subsidy measures that are related to terrace construction and maintenance. The first is an agro-environmental measure under Cyprus' Rural Development Program 2014–2020 that subsidizes the maintenance of existing terraces (MANRE 2019). In particular, the measure refers to the maintenance of traditional terrace walls that have collapsed (eg due to high rainfall and surface runoff), and the subsidy rate for vineyards is € 100/ha (US$ 114.20/ha). Mountain farmers were allowed to apply for the maintenance of collapsed terraces support measure once a year within the 2014–2020 period. Considering the responses of the winery owners, this subsidy scheme covered a very small fraction of the annual average maintenance cost. The second subsidy scheme fell within the National Support Programme for the Wine Sector 2014–2018, which was implemented in line with EU Regulation No. 1308/2013. This scheme subsidized both the construction of new and the maintenance of existing drystone walls at a much higher rate than the Rural Development Program, € 30/m^2 of terrace wall (US$ 34.26/m^2). The average length of terrace walls across the 11 surveyed wineries was ~1500 m/ha (Table 3), which implies a subsidy of € 45,000/ha (US$ 51,390/ha), on average.

TABLE 3 Terrace characteristics, construction, and maintenance cost.

Characteristic	Winery										
	Chandria	Kyperounta	Farmakas	Pelendri	Statos–Agios Photios	Ayia Mavri	Koilani	Omodos	Panayia	Vasa Koilaniou	Malia
Terraced vineyards with maintained drystone walls (%)	100	100	5	100	60	50	15	20	100	100	70[a]
Terrace height (m)	1.5	1.2–1.5	1.5	1.2–3.5	2.5	2–2.5	1	2	2–5	1–1.5	2–2.5
Terrace width (m)	6	2.5	8	2–5	15	10	10	8	3–20	4–80	15–50
Average length of terraces (running m/ha)	200–1500	4000	200	5000	450	300	300	2000	500–1000	200	1750
Terrace establishment labor cost (€/m)[b]	60	25	–	75	35		15	30	25		2
Terrace establishment material (eg stones) cost (€/m)	40	45	–	75	15		10	20	8		3
Total terrace establishment cost (€/m)	100	70	–	150	50	20	25	50	33	180	5
Annual terrace maintenance cost (€/ha)	5000	1000	–	3750	–	3600	3000	–	–	2000	–

[a] The terraces of the winery located in Malia are not supported by drystone walls but are vegetated to enhance stability; the costs refer to planting when the terraces are established.
[b] Conversion rate at time of study: € 1 = US$ 1.142.

There are, however, specific requirements; for example, the height of new drystone walls should be between 0.8 to 1.2 m. In our survey, we found that some of the existing traditional terraces were higher than these requirements (Table 3). Also, the maximum area per applicant was limited to 1 ha, while vineyard terraces that had already been subsidized through the Rural Development Program were excluded to avoid double funding. This subsidy scheme was certainly more attractive for the wineries because it covered a larger share of the terrace establishment cost, ranging between 20% for vineyards located at higher elevations up to full cost recovery for those at lower elevations. At the same time, this finding indicates that further research is required to establish more equitable and targeted policy measures.

To obtain further insights into the establishment and maintenance costs of mountain terraced vineyards, the Chandria and Pelendri wineries were asked to provide additional techno-economic details (Table 4). The vineyards of both wineries are located at higher elevations and on gabbro formations, thus representing the more costly terrace investments in Cyprus. The total terrace establishment cost, including the plantation cost, was € 313,400/ha (US$ 357,903/ha) in Chandria and € 832,500/ha (US$ 950,715/ha) in Pelendri. The highest share of the cost was attributed to the labor cost for wall construction and the cost of the stones (which also included their transport to the terrace sites). Torquati et al (2015) found that the cost of establishing terraced vineyards in Costa Viola (Reggio Calabria), Giano dell'Umbria (Perugia), and Lamole (Firenze) in Italy was € 78,168/ha, € 98,166/ha, and € 134,458/ha, respectively, based on 2012 values. When comparing these findings with the current study, it seems that establishing terraced vineyards in high mountainous regions in Cyprus can be up to 8 times more costly than in the reported Italian regions. Regarding vineyard management and terrace maintenance, the total annual cost was € 12,050/ha (US$ 13,761/ha) in Chandria and € 10,450/ha (US$ 11,934/ha) in Pelendri.

The average scores of a list of predefined reasons for investing in terrace construction and maintenance are presented in Figure 4. The reduction of soil erosion was by far the most important reason, according to winery owners. Their experience is backed up by the monitoring study of Camera et al (2018), who quantified the effectiveness of drystone terraces on mountain vineyards in Cyprus using sediment traps and laser scans and found an annual soil erosion rate between 2.4 to 3.2 mg/ha. They also reported that soil loss increases by a factor of 3.8 in degraded walls compared to well-maintained ones. Giannakis and Bruggeman (2018) estimated that for each 1 ton/ha increase in the annual soil erosion rate, the likelihood that European regions would attain high agricultural labor productivity decreased by 28%. The reduction of soil erosion is an important ecosystem service provided by terraces (Schwilch et al 2018), which is well appreciated by the mountain wineries. The provision of soil ecosystem services, including erosion control, water retention, and the enriched soil biota due to low-input farming methods, is also one of the main

TABLE 4 Detailed cost of establishing and maintaining mountain terraced vineyards.

Establishment and activity costs[a]	Winery	
	Chandria	Pelendri
Establishment cost—labor (€/ha)		
Land levelling, ploughing/harrowing, destoning	20,000	20,000
Terrace wall construction	150,000	375,000
Irrigation system installation	1000	6000
Planting	4000	3500
Staking/wiring	2500	5000
Total	**177,500**	**409,500**
Establishment cost—material (€/ha)		
Stones	100,000	375,000
Machinery (tractor)	2500	–
Irrigation (pipes, drippers)	3000	30,000
Planting equipment	1000	500
Vine plants	15,000	4000
Wire	7200	3500
Staking poles	7200	10,000
Total	**135,900**	**423,000**
Vineyard maintenance cost—labor (€/ha/y)		
Terrace wall maintenance	5000	2000
Ploughing/harrowing	700	1000
Fertilization	600	350
Plant protection and weed control	100	1000
Irrigation	250	100
Pruning	1250	2000
Toping/thinning	1500	150
Harvesting	1000	2000
Total	**10,400**	**8600**
Vineyard maintenance cost—material cost (€/ha/y)		
Stones	–	–
Machinery (tractor)	100	300
Fertilization	50	150
Plant protection and weed control	50	1000
Irrigation	1000	400
Pruning	450	–
Total	**1650**	**1850**

[a] Conversion rate at time of study: € 1 = US$ 1.142.

reasons why terraces are included in the greening CAP measures (Alliance Environnement 2017). Other important reasons for maintaining mountain terraces mentioned by the surveyed wineries were to facilitate agricultural works on mountain hill slopes and to improve land cover, while subsidies and enhanced sociocultural opportunities (eg landscape aesthetics and agritourism) received the fourth average scores (Figure 4).

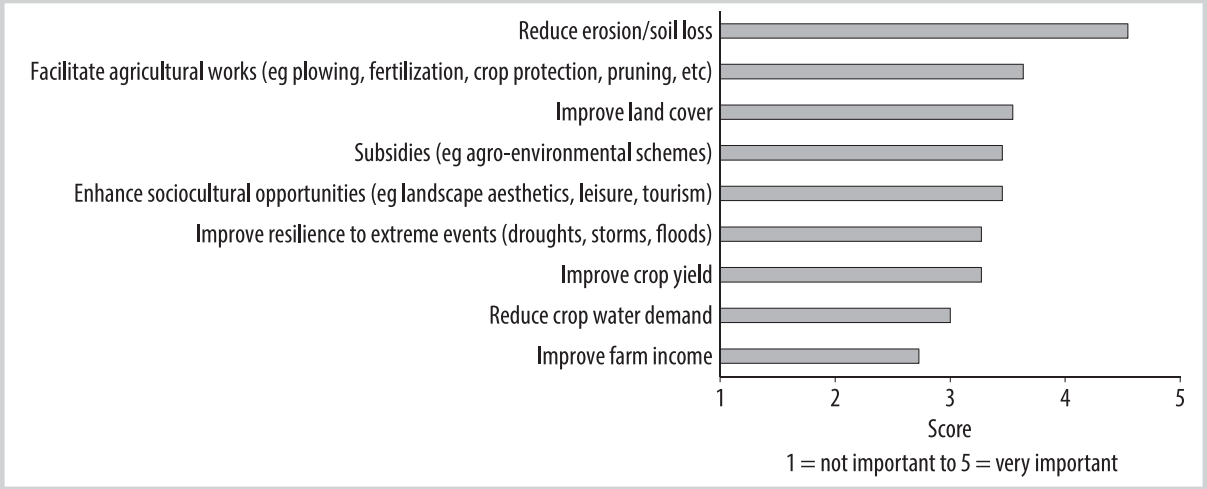
The winery owners were also asked to rank potential solutions that could be applied to revitalize mountain terrace farming (Figure 5). The 2 options that had the same average rank and were at the top of the ranking were "legal framework that supports the renting or selling of unused land" and "more or different agricultural subsidies." Apart from the socioeconomic issues associated with land abandonment in Cyprus, additional shortcomings include the small size and fragmentation of agricultural plots, the lack of road access, and issues relating to ownership rights. Demetriou et al (2012) suggested that land consolidation and reallocation using an integrated planning and decision support system could help to overcome these issues. The concept of "land banks" is a potential solution that has been discussed and applied in some European countries to overcome the risk of farmland abandonment (Terres et al 2015), such as in Italy (Strambi 2015) and Spain (Corbelle-Rico et al 2012). Another option that ranked relatively high among the respondents was "financial incentives for improved agritourism facilities." In fact, some of the wineries, such as the one located in Panayia, were planning to invest in agritourism facilities in the near future. The reconstruction of traditional landscapes can enrich terraced agriculture by stimulating the development of recreational tourism (and thus an additional income source for the mountain population) while helping to protect the environment (Torquati et al 2015).

Production output and financial viability

The grape and wine production output, the cost, and the gross returns per bottle of the surveyed mountain wineries are listed in Table 5. The yield from the vineyards managed by the wineries (ie grapes produced in owned and rented land) enables comparison between the sampled case studies. Based on the managed vineyard areas and production output, the computed average yield across the 11 wineries was 4.4 ton/ha, which is above the 3.1 ton/ha average that is reported in national agricultural statistics for wine-growing areas in the period 2009–2017 (Cystat 2017). However, there was large yield variation between the surveyed wineries. One reason could be the varieties grown and the different vineyard management practices applied at each winery vineyard. Also, the low yield of some winery vineyards, as explained by the respondents, was due to the young age of the vines, and the yield was expected to increase in the coming years.

The wine production, measured in bottles produced per year, is indicative of the size and production capacity of each winery. Two mountain wineries (located in Kyperounta and Panayia) were producing a relatively high amount of wine, around 300,000 bottles/year or more. Another interesting finding is the share of own-produced grapes used in wine making. The wineries located in Chandria, Farmakas, Malia, and Vasa Koilaniou relied almost exclusively on their own grapes, while only 6% of the wine produced in Kyperounta was obtained from the winery's vineyards. In most cases,

FIGURE 4 Reasons for constructing or maintaining drystone terraces; average score is based on the responses of 11 winery owners.



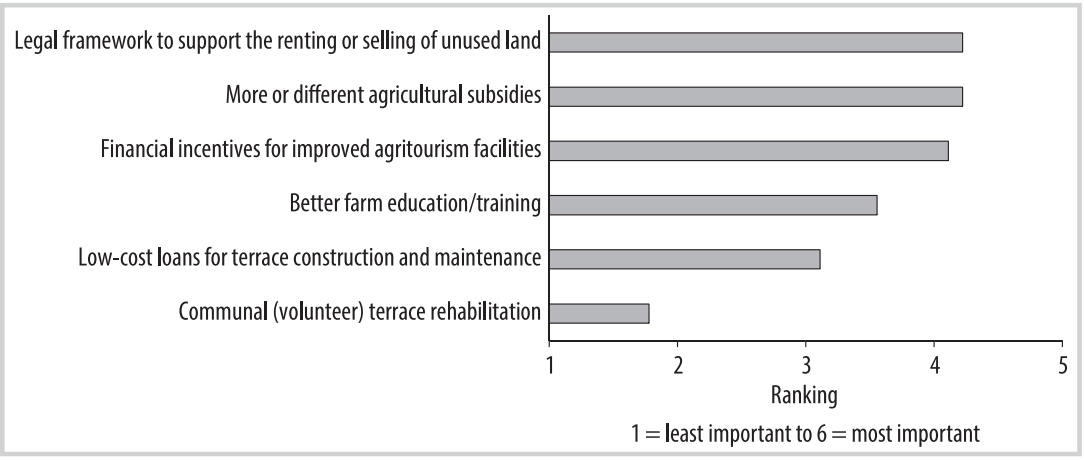
wineries purchased grapes from other farmers based on contract agreements. These agreements not only define the quantities and the price but also the quality of grapes. To ensure that the quality of the purchased grapes is adequate for wine production, the agronomists working for the wineries often provide vineyard management advice to the farmers with whom they collaborate. This strategy reduces the grape production cost for the wineries, but it also benefits other mountain grape producers, as the sale of the produced grapes is ensured. In addition, the wineries are among the few rural business in the mountain areas, and so their existence benefits and sustains the mountain agriculture of nearby communities.

Regarding the trading of wine produced, most wineries had sales agreements with local stores, while small quantities were sold to winery visitors. Exceptions to this rule were the wineries located in Omodos and Ayia Mavri, where 80% and 50% of the wine was sold to visitors, respectively. Another interesting example is the trading collaboration of Pelendri, Koilani, and Vasa Koilaniou wineries. These wineries established a distribution company that exclusively trades their wines. Kyperounta winery, on the other hand, has its own distribution company. It is noteworthy that although 9 out of 11 wineries also export their wines, the exported production averaged just 5% per winery. The average gross profit margin of all surveyed wineries was € 226,595 (US$ 258,771), which implies a general efficiency in the production process. Although there was a wide range of costs and revenues for each winery, this metric is informative when comparing across the different wine regions and at the field (per hectare) level. The gross profit margins in Pitsilia, Vouni Panagias–Ampelitis, and Krasochoria regions were € 24,406/ha (US$ 27,872/ha), € 13,396/ha (US$ 15,298/ha), and € 8,368/ha (US$ 9556/ha), respectively. This is an interesting finding, since the wineries located at higher elevations (Pitsilia region) had bigger production costs (including terrace construction and maintenance), but at the same time, they were able to market their products more efficiently, in general. Thus, although the production conditions are more difficult and costs are bigger at higher elevations, investment in productive agriculture can be an efficient and financially viable business.

Parameters of success, concerns, and future visions

When asked if they considered their business to be successful, all surveyed wineries responded positively. This success can be partly explained by the decisions made by winery owners. As shown in Figure 6, these decisions are

FIGURE 5 Solutions to revitalize rural mountain communities and terrace farming; ranking is based on the responses of 11 winery owners.



 https://doi.org/10.1659/MRD-JOURNAL-D-21-00031.1

FIGURE 6 Support in vineyard management decisions; average score is based on the responses of 11 winery owners.

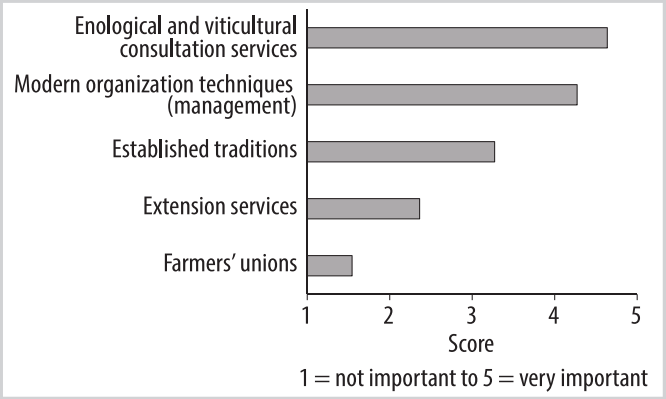
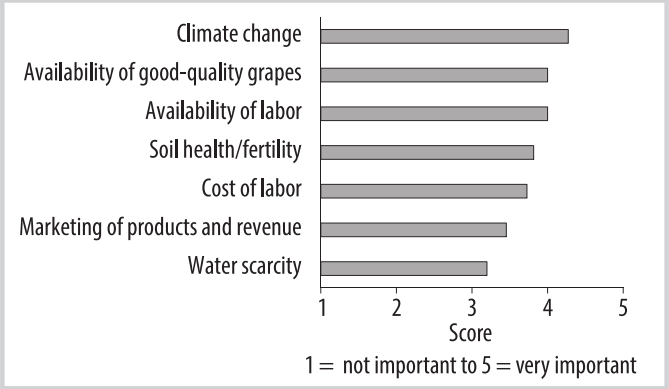


FIGURE 7 Major concerns; average score is based on the responses of 11 winery owners.



taken in consultation with enologists and viticulture professionals. In addition, the modern management option was highly scored. The use of information and communications technologies plays a key role in what Milone and Ventura (2019) called "new generation farmers." With an open question, the respondents were also asked to define the factors determining the success of mountain wineries (Table 6). The quality of grapes and wines produced was mentioned by 9 out of 11 wineries, while the mountain terroir, marketing, and sales/profit were mentioned by 7 wineries.

Terroir has been defined as "a unique and delimited geographic area for which there is a collective knowledge of the interaction between the physical and biological environment and applied vinicultural practices. The interaction provides unique characteristics and creates a recognition for goods originating from that area" (van Leeuwen 2010: 274). As terroir is typically associated with distinctiveness, the marketing value of products with a defined terroir tends to be higher (Cross et al 2011). In France and Italy, the concept of terroir is the basis for certification and geographical indication, protection of origin, and labeling (Lamine et al 2019). In Spain, there is no terroir characterization; however, as González and Dans (2018) noted, the emergence of the *terroirist* social movement created rural networks of small-scale farmers that aim to produce quality wines with added value. Similar to Spain, there are no defined terroir regions in Cyprus yet; however, the respondents considered that the mountain growing conditions are unique and therefore add to the value and success of their wines.

The most important concern identified by mountain wineries, as shown in Figure 7, is climate change. Interestingly, the respondents did not relate this issue to water scarcity, since the Troodos aquifer system is not as depleted as the coastal aquifers of Cyprus (Zoumides et al 2013, 2014). Mozell and Thach (2014) explored the consequences of climate change on the global wine industry and noted that premium wine grape production that occurs in very narrow climate ranges can be severely affected by changes in temperature. According to winery owners, the microclimate determines to a great extent the character of the wines produced at each site. Nicholas et al (2011) studied the effects of climate variability on the phenolic composition of pinot noir grapes cultivated in California's North Coast. Their findings indicate that the tremendous variability observed within vineyards implies that further research and monitoring are needed to understand the influence of climate and temperature on inter alia canopy, and plant and soil water status, and therefore the effects on grape and wine quality characteristics. Other important issues of concern that were revealed by the responses are the availability of good-quality grapes and the scarcity of labor. Both issues are associated with the depopulation of rural communities and the gradual abandonment of mountain agriculture.

Despite these concerns, the majority of the surveyed wineries were optimistic about the future of their business and mountain agriculture in general. The establishment of local wineries is the main driver that sustains mountain farming in the area, and it creates prospects for other associated industries (eg agritourism) to be developed in the near future. As noted by Farmaki (2012), much of the promotion surrounding agritourism in Cyprus revolves around the activities that can be performed in the Troodos Mountains, ranging from nature-based activities to visiting wineries. Efforts to enhance agritourism began in the mid-1990s with the aim of diversifying the mass "sun and sea" tourism model (Farmaki 2016). These efforts continue to this day and include, for instance, financial incentives to renovate and convert traditional houses into guesthouses. The number of licensed holiday accommodations in the Troodos region increased from 49 in 2006 to 256 in 2017 (CDMC 2019). As indicated by 8 out of 11 respondents, the creation of family wineries implies that more people have become aware of local wines, while the competition between the wineries is a motivation to further improve the quality of the wines they produce. The surveyed wineries shared a number of common visions for the future, which can be summarized as follows:

- Ensure the sustainability of their business and leave something for their children and the future generations, for example, continue a tradition, create points of reference and excellence regarding mountain farming;
- Improve the quality of wine produced, especially from local varieties, so that it is competitive locally and internationally;
- Increase production from current vineyards by utilizing abandoned land;
- Revitalize the mountain communities and provide employment opportunities, so families can return and

TABLE 5 Annual wine production output, costs, revenues, and trading channels. (Table extended on next page.)

Inputs and outputs[a]	Winery				
	Chandria	Kyperounta	Farmakas	Pelendri	Statos–Agios Photios
Grape production from own vineyards (tons)	60	25	22	30	25
Grapes purchased from other farmers (tons)	–	375	–	200	260
Portion of own grapes used in wine production (%)	100	6	100	13	9
Yield in vineyards managed by wineries (tons/ha)[a]	4.0	1.6	1.0	3.8	1.3
Wine production (750 mL bottles)	40,000	375,000	20,000	200,000	290,000
Total variable cost of grape production: labor, mechanical, fertilizers, etc (€)	30,000	163,000	66,000	270,000	31,350
Total variable cost of wine production: labor, operation, winemaking, etc (€)	133,000	278,000	45,000	500,000	608,000
Total revenue from wine sales (€)	150,000	1,400,000	90,000	1,000,000	680,000
Other revenue, eg catering, tasting, etc (€)	5000	10,000	110,000	25,000	–
Subsidies (€)	7500	10,000	1500	4000	5000
Value of wine stock (€)	30,000	600,000	35,000	500,000	1,795,650
Gross profit margin (€)[b]	–500	979,000	90,500	259,000	45,650
Gross profit margin per hectare (€/ha)[b]	–33	61,188	4095	32,375	2341
Trading channels					
Direct sales at the winery (%)	20	1	20	10	5
Sales agreements with local stores (%)	72	–	80	–	80
Exports (%)	8	5	–	8	15
Private distribution network (%)	–	94	–	82	–

[a] Conversion rate at time of study: € 1 = US$ 1.142.
[b] Own elaboration based on the responses of winery owners (see Table 2 for vineyard area).

raise their children in an environment outside the cities and have a good standard of living.

The survey was conducted in 2 phases: The main data were gathered in 2017, and the validation of data with clarification questions on the economics of wineries was conducted in early 2020. As such, the impacts of the coronavirus disease 2019 (COVID-19) pandemic are not reflected in the responses. It is, however, evident that the wine market at European and international levels has been affected, both in the lockdown phase, and in the new normal reality post-2020. Indicatively, the Comité Européen des Entreprises Vins (CEEV 2020) reported a decrease of global wine trade of 17% (equivalent to € 1.8 billion) in the period March–June 2020, compared to 2019. At EU level, winery turnover decreased by 35% in the first semester of 2020; the impact of the pandemic is more evident in microcompanies. In Cyprus, wine production, consumption, and exports were, respectively, 9, 48, and 30% lower in 2019–2020 compared to 2017–2018, based on data provided by the Department of Agriculture. The high reduction in consumption is linked to the restricted social events (eg weddings, graduation ceremonies, etc), where wine is typically consumed, during the COVID-19 pandemic. The sustainability of the wine sector will depend on its capacity to recovery in the next 2–3 years and to adapt to the new realities. For instance, in the first phase of the crisis, wine e-commerce at the global level increased by 180% (CEEV 2020). Although this reflects only 1% of wineries' turnover, it could potentially grow steadily, considering the new post-COVID-19 realities. At the EU level, an efficient support package for the quick recovery of the on-trade channel has been discussed, while, in Cyprus, a support package to enhance the competitiveness and export capacities of wineries was put forward in April 2021. It remains to be seen how fruitful these policies are and whether mountain wineries can remain successful in the near future, following the COVID-19 shock.

Conclusion

Terraces are a landscape characteristic of mountain regions around the globe. In the Mediterranean basin, these farming systems are associated with the cultivation of grapes. While studies on terrace abandonment are pervasive, there are very few studies that analyze viable mountain production systems. To contribute to the recent and growing interest in the renaissance of agricultural mountain terraces, this study aimed to shed light on the often-overlooked socioeconomic drivers, prospects, and

TABLE 5 Extended. (First part of Table 5 on previous page.)

Inputs and outputs[a]	Winery					
	Ayia Mavri	Koilani	Omodos	Panayia	Vasa Koilaniou	Malia
Grape production from own vineyards (tons)	18	290	30	95	50	160
Grapes purchased from other farmers (tons)	40	200	80	150	2	–
Portion of own grapes used in wine production (%)	31	59	27	39	96	100
Yield in vineyards managed by wineries (tons/ha)[a]	6.0	13.7	1.1	6.1	6.7	3.3
Wine production (750 mL bottles)	40,000	220,000	80,000	192,000	40,000	50,000
Total variable cost of grape production: labor, mechanical, fertilizers, etc (€)	29,100	55,000	42,000	42,000	47,000	53,924
Total variable cost of wine production: labor, operation, winemaking, etc (€)	90,000	470,000	150,000	350,000	140,000	192,184
Total revenue from wine sales (€)	150,000	1,000,000	370,000	750,000	170,000	250,377
Other revenue, eg catering, tasting, etc (€)	–	10,000	–	5000	17,500	–
Subsidies (€)	1300	5000	8000	16,000	3500	23,429
Value of wine stock (€)	150,000	500,000	225,000	160,000	200,000	141,165
Gross profit margin (€)[b]	32,200	490,000	186,000	379,000	4000	27,698
Gross profit margin per hectare (€/ha)[b]	10,733	23,113	6889	24,452	533	571
Trading channels						
Direct sales at the winery (%)	50	10	80	20	3	–
Sales agreements with local stores (%)	45	–	20	77	–	98
Exports (%)	5	1	–	3	1	2
Private distribution network (%)	–	89	–	–	96	–

TABLE 6 Factors determining the success of mountain wineries.

Winery	Success factor					
	Quality of grapes and wine	Mountain terroir	Niche products	Marketing	Sales/profit	Confidence in mountain agriculture potential
Chandria	✓	✓	✓	✓		✓
Kyperounta		✓		✓	✓	
Farmakas	✓	✓				✓
Pelendri	✓	✓	✓	✓		✓
Statos–Agios Photios	✓	✓	✓	✓	✓	✓
Ayia Mavri	✓		✓		✓	
Koilani	✓	✓	✓	✓	✓	
Omodos	✓				✓	
Panayia	✓	✓	✓		✓	✓
Vasa Koilaniou	✓			✓		✓
Malia				✓	✓	
Total no. of wineries	**9**	**7**	**6**	**7**	**7**	**6**

visions of farmers, using the mountain family wineries of Cyprus as a case study. The bottom-up approach and the outcomes of the study provide insights and a broader view that can be of relevance to other terraced farming areas, given that the challenges and opportunities are often common in such environments. For instance, although investments in drystone terraces were found to be costly, the wineries cherish their role as sustainable and viable mountain agribusiness and recognize that beyond the historical heritage, landscape aesthetics, and cultural values, terraces provide important ecosystem services, such as the prevention of environmental risks, the control of soil erosion, and the creation of a unique mountain terroir. Furthermore, the semistructured survey revealed that farmers are concerned and well aware of global challenges, such as climate change. At the same time, the shared vision for a future where abandoned mountain terraces can be productively utilized is indicative of the prospects for job creation, while the spin-off effects and synergies with complementary industries can be leveraged to effectively sustain mountain livelihoods. These attributes are particularly important for creating well-informed and innovative regional and rural development policies at European, national, and territorial levels. The development prospects of mountain farmers need to be supported and enhanced, while the site-specific challenges that they face need to be better understood and taken into account during this process to move toward a new, sustainable, effective, and equitable policy paradigm. The survey developed and applied in this study (see Appendix S1, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-21-00031.1.S1) is a useful tool for initiating a dialogue with farmers. Similar studies are encouraged, so as to create a global collection of mountain agriculture success stories.

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Supplemental material

APPENDIX S1 Questionnaire.
TABLE S1 Grape varieties.

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