The current state of Pantelleria's agricultural system

A sustainability report

Nicoletta Maestrini, Paul van den Berge, Eugenio Giacopelli

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Research Institute of Organic Agriculture FiBL | Ackerstrasse 113 | Postfach 219
5070 Frick | Switzerland | Phone +41 62 865 72 72 | info.suisse@fibl.org | www.fibl.org

Table of Contents

1. Foreword 4
2. Methodology 4
3. Pantelleria: context and characteristics 5
3.1 Climate 6
3.2 Agriculture 8
3.2.1 Wine 9
3.2.2 Capers 10
3.2.3 Other crops 11
4. Sustainability of the farming system in Pantelleria 11
4.1 Overall assessment 11
4.2 Social well-being 14
4.2.1 Youth empowerment and labour shortages 14
4.2.2 Producers collaboration 14
4.2.3 Extension and training 14
4.2.4 Salaries and working conditions 15
4.3 Economic resilience 15
4.3.1 Diversity of economic activities 15
4.3.2 Stability of production 16
4.3.3 Price premiums and value creation 16
4.3.4 Producers Empowerment 16
4.4 Environmental integrity 17
4.4.1 Soil fertility management 17
4.4.2 Use of agrochemicals 18
4.4.3 Biodiversity conservation 18
4.4.4 Technical innovation 19
4.4.5 Use of energy 19
4.4.6 Climate resilience 20
4.5 Good governance 20
4.5.1 Awareness and preservation of local identity 20
4.5.2 Farm succession 20
4.5.3 Land governance 21
4.5.4 Creation and transfer of knowledge 21
5. Stakeholders' views and perceptions 22
6. Recommendations for a sustainable farming system 22
7. References 25

List of figures

Figure 1: FiBL_The island seen from above..... 1
Figure 2: Parco Nazionale Isola di Pantelleria_Typical "dammusi" houses with garden. 5
Figure 3: FiBL_Typical dry-stone walls and olive trees grown close to the ground.6
Figure 4: Climate-data.org (ECMWF data) _1991 – 2021: Min. Temperature °C (°F), Max. Temperature °C (°F), Precipitation / Rainfall mm (in), Humidity, Rainy days. Data: 1999 - 2019: avg. Sun hours..... 6
Figure 5: Mosso, D et.al_Irradiance (left) ad wind speed (right) maps of Pantelleria island..... 7
Figure 6: FIBL_A Pantescan garden..... 7
Figure 7: FiBL_A typical head-trained bush vine field..... 8
Figure 8: Parco Nazionale Isola di Pantelleria _A head-trained Zibibbo grapevine grown in a pit..... 9
Figure 9: FiBL_The caper flower. 10
Figure 10: FiBL_Oregano bushes. 11
Figure 11: FiBL_Diagram illustrating the sustainability of Pantelleria's farming system divided into 4 components. 13

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1. Foreword

Pantelleria, also known as the "black pearl of the Mediterranean", is a small island situated 110 kilometres from Sicily and 65 kilometres from Tunisia. Here, agriculture has played a key role since prehistoric times. Thanks to its microclimates, the fertility and diversity of its volcanic soils, and the ingeniousness and uniqueness of its farming techniques, Pantelleria has experimented with different types of crops across millennia: from cotton and grains to grapevines, capers, aromatic herbs, olive and fruit trees, local farmers have always been forced to reinvent themselves and learn new cultivation techniques to adapt to the island's harsh climate conditions, especially strong winds and scarce rainfall.

Despite its long and successful agricultural history and thousands-year-old agricultural practices passed down through generations, Pantelleria has been struggling with an increasing abandonment of agricultural land and a gradual shift into other professions since the 1980s, which has resulted in a drastic reduction of agricultural outputs and product sales.

This report analyses the current status of Pantelleria's agricultural system in terms of its social, economic, and environmental sustainability. Furthermore, it illustrates some of the key prospects for improvement and seeks to formulate recommendations to strengthen the farming system's sustainability in the years to come.

2. Methodology

After conducting preliminary desk research to better understand Pantelleria and its geographical, social and agricultural context, experts of the Department of International Cooperation at the Swiss Research Institute of Organic Agriculture (FiBL) travelled to Pantelleria and mainland Sicily to conduct in-person interviews with farmers, processors, agronomists, professors, researchers, and local government officials in order to better understand the current challenges and opportunities for the island's farming system.

In order to assess the social, environmental and economic sustainability of the agricultural system in Pantelleria, the FiBL Department of Food System Sciences developed relevant indicators. Each individual indicator was assigned a score on a scale from 0 (=not at all sustainable) to 4 (=very sustainable). These sustainability indicators were selected on those defined by the TAPE (Tool for Agroecology Performance Evaluation) and the SMART (Sustainability Assessment of Food and Agriculture Systems) methodologies. While the first tool was developed by the United Nations Food and Agriculture Organisation (FAO) to assess the sustainability of agroecological system at the farm/household level (FAO, 2024), the SMART methodology was created by FiBL experts and includes "*a sophisticated rating methodology as well as a comprehensive pool of indicators*" (FiBL, 2024).

Subsequently, all information provided by the interviewees and the literature research was analysed and the single indicators graded according to the defined rating scales. The data was later fed into a diagram (Figure 11) to illustrate the key themes that arose

during the interviews and visualise their performance in terms of environmental, social, and economic sustainability.

3. Pantelleria: context and characteristics

Pantelleria counts 7407 inhabitants who are mainly engaged in the public sector, construction, agriculture, and tourism (ISTAT 2021). The island's total surface is around 84 km^2, with a maximum altitude of 836 metres above sea level. The island's territory has been a regional nature reserve since 1998. In 2016, a large area of the island (80% of the total surface) was designated as a National Park, now called "*Parco Nazionale Isola di Pantelleria*".

Figure 2: Parco Nazionale Isola di Pantelleria_Typical "dammusi" houses with garden.

Pantelleria's unique geographic location has historically made it a strategic point along Mediterranean trade routes, attracting various dominations. Colonised by the Phoenicians in the 9th century B.C., the island was transformed into a significant commercial hub with the establishment of a large seaport and the introduction of the *"vite ad alberello"* (head-trained bush vines reaching a maximum height of 30-40cm) and underground water storage tanks (Tudisca et al., 2011). The Arab settlers in the 9th century A.C. left a major imprint on Pantelleria's history and landscape. Their influence is still visible today through the Arabic-derived names of many localities and the iconic "*dammusi*" houses (Fig. 2), characterised by their cubic stone structure and rooftop buckles for rainwater collection.

Figure 3: FiBL_Typical dry-stone walls and olive trees grown close to the ground.

The beauty and variety of natural and human-made landscapes in Pantelleria are a key testimony to the island's rich cultural and historic heritage and attract thousands of tourists every year. The remoteness of the island, the low number of tourist facilities, and the "not so family-friendly, rocky beaches" have made Pantelleria a niche destination for affluent tourists looking for privacy; this trend has also made tourism a very attractive income source for local residents.

3.1 Climate

Pantelleria's climate is typically Mediterranean, with a mean annual temperature of 18.1 °C and monthly mean temperatures ranging from 11.7 to 25.6 °C. The mean annual precipitation is 408 mm, concentrated over the autumn and winter seasons (Fig. 3). However, climate change is making rainfall scarcer: between 2023 and 2024, no rain fell for a whole year, affecting crop production.

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	13.7 °C (56.6) °F	13.1 °C (55.5) °F	14.1 °C (57.4) °F	15.6 °C (60.2) °F	18.2 °C (64.8) °F	21.8 °C (71.2) °F	24.6 °C (76.4) °F	25.7 °C (78.2) °F	24.1 °C (75.4) °F	21.8 °C (71.2) °F	18.3 °C (64.9) °F	15.2 °C (59.4) °F
Min. Temperature °C (°F)	12.9 °C (55.3) °F	12.3 °C (54.1) °F	13.4 °C (56.1) °F	15 °C (58.9) °F	17.5 °C (63.5) °F	21 °C (69.8) °F	23.9 °C (75.1) °F	25 °C (77) °F	23.4 °C (74.1) °F	21 °C (69.8) °F	17.4 °C (63.4) °F	14.4 °C (58) °F
Max. Temperature °C (°F)	14.4 °C (58) °F	13.9 °C (57) °F	14.8 °C (58.6) °F	16.3 °C (61.4) °F	18.9 °C (66.1) °F	22.6 °C (72.7) °F	25.4 °C (77.8) °F	26.4 °C (79.5) °F	24.8 °C (76.6) °F	22.5 °C (72.4) °F	19.1 °C (66.4) °F	16 °C (60.9) °F
Precipitation / Rainfall mm (in)	71 (2)	62 (2)	45 (1)	29 (1)	13 (0)	3 (0)	1 (0)	4 (0)	43 (1)	71 (2)	78 (3)	76 (2)
Humidity(%)	72%	72%	77%	80%	82%	82%	81%	80%	76%	77%	74%	71%
Rainy days (d)	8	7	5	4	2	1	0	1	4	6	8	9
avg. Sun hours (hours)	7.0	7.7	9.2	10.7	12.0	12.8	12.6	11.8	10.1	8.8	7.7	6.9

Figure 4: Climate-data.org (ECMWF data) _1991 – 2021: Min. Temperature °C (°F), Max. Temperature °C (°F), Precipitation / Rainfall mm (in), Humidity, Rainy days. Data: 1999 - 2019: avg. Sun hours.

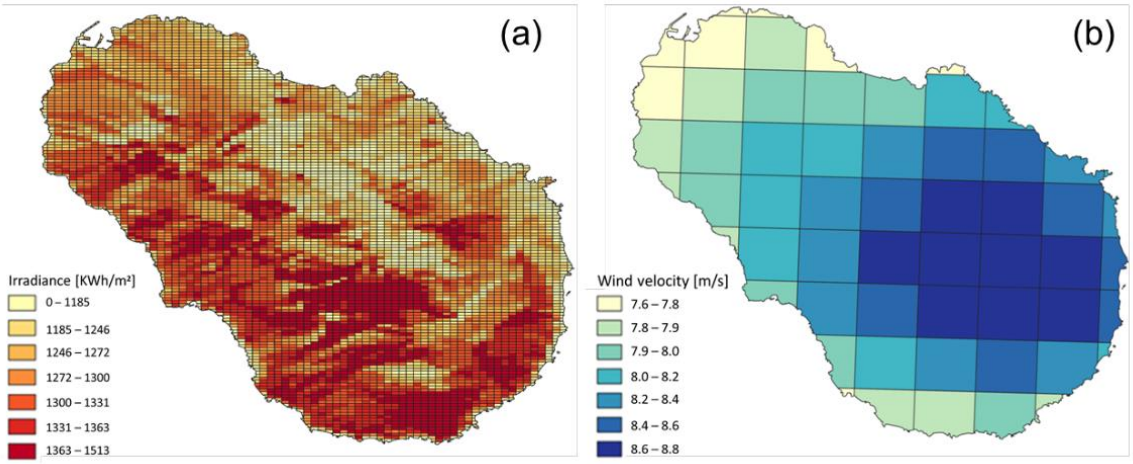

Figure 5: Mosso, D et.al_Irradiance (left) ad wind speed (right) maps of Pantelleria island.

Pantelleria is highly exposed to winds (Fig. 4), especially warm winds from the south. This characteristic has shaped the agricultural and natural landscape and determined the farming practices adopted by farmers. Examples are the "vite ad alberello" system, which reduces the grapevine tree area exposed to strong winds and any possible damage to the plant, and the "*Giardini panteschi*" (Pantescan gardens), which are circular walls containing one or two citrus fruit trees for wind protection (Tudisca et al., 2011; Mosso et al., 2024).

Figure 6: FIBL_A Pantescan garden.

Despite its small size, Pantelleria features a variety of altitudes and ecosystems, each with a higher or lower exposure to winds. Local farmers have managed to harness these microclimates to their own advantage by growing different crops in different areas. In fact, the grape harvest can take place with one month's difference depending on whether the grapes grow in Contrada Martignana or Contrada Zibà, which are only 13 km apart.

3.2 Agriculture

Farming has played a major role in the island's economy for millennia due to its fertile volcanic soils and the ability of its farmers to adapt to harsh climate conditions and lack of water sources. Due to the lack of permanent water bodies and rivers, as well as scarce rainfall, *"Pantescan farmers developed ingenious agricultural practices based on water management techniques to sustain a wide range of agricultural products that flourished and deeply influenced the island's identity" (*Aumeeruddy-Thomas et al., 2024). Agriculture flourished under Arab rule, introducing crops such as olives, capers, and "*Zibibbo*" grapes (also known as Muscat of Alexandria), which were dried for export (Tudisca et al., 2011). In the 1700s, cotton was the main crop, followed over the centuries by grains and eventually zibibbo grapes. Traditional agricultural practices have therefore played a major role in shaping the morphology and architecture of today's island and represent a key element to consider for future development of the island.

Figure 7: FiBL_A typical head-trained bush vine field.

A recurring phrase can be heard across the island: "*agricoltura eroica*" (heroic agriculture) because farming in Pantelleria has never been an easy feat. Strong winds, low precipitation, hot summers and steep, terraced land have constantly forced farmers to look for innovative ways to prosper. All across the island, most crops are cultivated close to the ground, utilising width rather than height to withstand wind and optimise water resources. The "vite ad alberello" reaches a maximum height of 30-40cm from the ground and is surrounded by a pit that collects dew and protects the plant from wind damage (Tudisca et al., 2011) This cultivation method has been listed in the UNESCO Representative List of the Intangible Cultural Heritage of Humanity since 2014 (UNESCO, n.d.). The same concept applies to centuries-old olive trees, which barely reach 1-1.5 meters in height. Stone terraces and dry-stone walls *("muretti a secco")* are also abundant across the islands, having played a key function in safeguarding biodiversity, ensuring optimum soil humidity, and protecting crops from strong winds and extreme heat. The island's diverse landscapes show how nature, agriculture, and architecture are inextricably connected to each other.

3.2.1 Wine

Figure 8: Parco Nazionale Isola di Pantelleria _A head-trained Zibibbo grapevine grown in a pit.

Pantelleria shows a strong viticulture vocation, hosting 83.2% of the 892 vineyard farms and over 88% of the approximately 1'150 hectares that constitute the vineyard area of the Sicilian Minor Islands (Eolian and Egadi islands). Over the past decade, Pantelleria's viticulture has grown by 9.8% in terms of area, continuing a historical tradition evidenced by the analysis periods, revealing that over 80% of the vineyard area was planted over thirty years ago (Regione Sicilia, 2016). However, it is important to note that most of the new vineyard area has been planted and cultivated by the island's two largest wine producers, Pellegrino SA and Donnafugata SA.

In the 1960s, out of 8400 hectares of available arable land, 5400 were cultivated with "*Zibibbo*" grapes. 60% of the grapes collected were sold as "*uva da tavola*" (fresh table grapes), while the rest were used for different white wines, including Passito or Moscato di Pantelleria, which were granted the Controlled Designation of Origin (DOC) status in 1971 (Tudisca et al., 2011).

Nowadays, the situation looks very different: only 400 hectares of arable land on the island are cultivated with Zibibbo grapevines. Of these 400 hectares, about 100 are cultivated by and for Donnafugata. Reliable data on the sourcing area of Pellegrino was not available, as they do not cultivate land themselves but only buy grapes from individual producers. The remaining land has mostly been abandoned or converted into tourism infrastructure. Despite the significant drop in the island's cultivated area, Pantelleria's agricultural economy still revolves around the production of the Zibibbo grape.

The unique age-old practice of cultivating head-trained bush grapevines has been sustained by generations of farmers on Pantelleria. Harvesting the wine grapes by hand begins in late July, marking a ceremonial event that underscores the community's deep connection to grapevine cultivation. This knowledge is passed down within families through oral tradition and practical instruction, fostering a sense of identity and

preservation among the island's inhabitants (UNESCO, n.d.). However, since the arrival of Donnafugata and Pellegrino, small-scale production of wine has been struggling to keep up with competition, soaring living costs and a lack of manpower.

3.2.2 Capers

Pantelleria, similarly to other minor Sicilian Islands (Ustica, Linosa, Favignana, and others), is a very important caper producer at the global level. Capers are the second most important crop for the island, with a cultivated surface of about 100 hectares (as opposed to the 400 hectares cultivated with Zibibbo grapevines). Pantelleria capers are also the only ones whose production is regulated through the Protected Geographical Indication (IGP) EU designation, which makes them a world-renowned delicacy. Today, the *"Cooperativa dei Capperi"* (Capers Cooperative), founded in 1971, is the only agricultural cooperative that has survived on the island throughout the years. It counts 460 members of which only 178 are active producers, with a total yield of 647 quintals in 2021/22, only half the yield of 2000 (Cappadona, 2022). The management of the Cooperativa dei Capperi informed us that its members do not regard the Cooperative as a structure run by and for the producers, but rather as a commercial buyer of capers. The willingness of the smallholders to collaborate in a cooperative structure is almost inexistent. In the recent past, three wine-cellar cooperatives had to file for bankruptcy. In 1998, the Cooperativa dei Capperi tried to again establish a cooperative for wine production but failed because of the lack of interest (and possibly trust) by the grape producers.

Figure 9: FiBL_The caper flower.

3.2.3 Other crops

Figure 10: FiBL_Oregano bushes.

Besides wine and capers, other delicacies produced on the island include aromatic herbs (especially oregano), fresh olives and olive oil, and several fruits (mostly citrus). Some farms grow a mix of these crops in order to diversify their offer and strengthen their resilience to climate shocks or fluctuating market demand. However, the quantity of these products is limited and is often sold locally.

4. Sustainability of the farming system in Pantelleria

4.1 Overall assessment

When assessing the overall sustainability of Pantelleria's farming system, there are a few strengths that immediately stand out: first, the market value and recognition of Pantelleria's products, especially capers and Passito di Pantelleria, are extremely high. The ancient and ingenious farming techniques used to cultivate these crops require heavy and lengthy manual work (e.g. hand picking, shovelling pits), and buyers all around the world very much seem to appreciate the hard work that goes into these delicacies. In addition, Pantelleria's unique climate and soil composition strongly impact the organoleptic quality of these crops, adding further value to the final products. At the same time, the farmers' identity is very much linked to traditions, with local varieties and ancient techniques still considered as a source of pride.

Also, the farming system's resilience and ability to adapt to climate and market shocks is strong. The island's harsh climate and successful farming history have made Pantelleria a place where everything is possible (if the willingness is there). Over millennia, Pantelleria has experimented with many different crops to adapt to market trends and climate conditions, and it managed to protect its two main products under IGP and DOC certifications. However, the situation is changing quite rapidly.

In the last four decades, Pantelleria has been experiencing an agricultural crisis, marked particularly by the abandonment of agricultural land. Besides the harsh climatic and

terrain conditions farmers have to work with, the main reasons for this crisis seem to be rather social: with the youth emigrating outside of Pantelleria because of a lack of attractive jobs, a dramatic lack of manpower, and increasing competition with large wineries, smallholder producers are struggling to survive.

Since the 1990s, several farmers have turned to construction, tourism, and public sector jobs (or, in most cases, a combination of these) to make ends meet, and today, many of them only practice agriculture as a side job or hobby. Consequently, the utilised agricultural area of the island's total territory, which stood at 81.6% in 1929, has now decreased dramatically (Rühl et al., 2005). Today, Pantelleria counts about 900 farms, with an average farm size of 1.87 hectares and a total agricultural land area of 1,680 hectares, representing 20% of the island's total surface area (8,450 hectares). At the end of the 1980s, grape production was around 100'000 quintals, while caper production was around 10'000 quintals. Today, the production of both crops has declined considerably, with an estimated 15'000 q of grapes and 1'000 q of capers (*Clean Energy for EU Islands, 2020*).

The overall sentiment perceived on the island is that the health status of Pantelleria's farming system is in decline. However, Pantelleria's National Park, the local government, and individual residents seem to be committed to finding concrete solutions to make agriculture flourish again.

The diagram below (Figure 11) illustrates the sustainability of Pantelleria's farming system to date. It is divided into four areas: social well-being, good governance, environmental integrity, and economic resilience. Each area includes the sustainability indicators developed to assess the farming system's sustainability, as explained in the methodology chapter. The score for each indicator is visible through the blue line, which moves from the centre towards the edges of the circle depending on the sustainability performance. Each indicator will be further assessed in the next chapter.

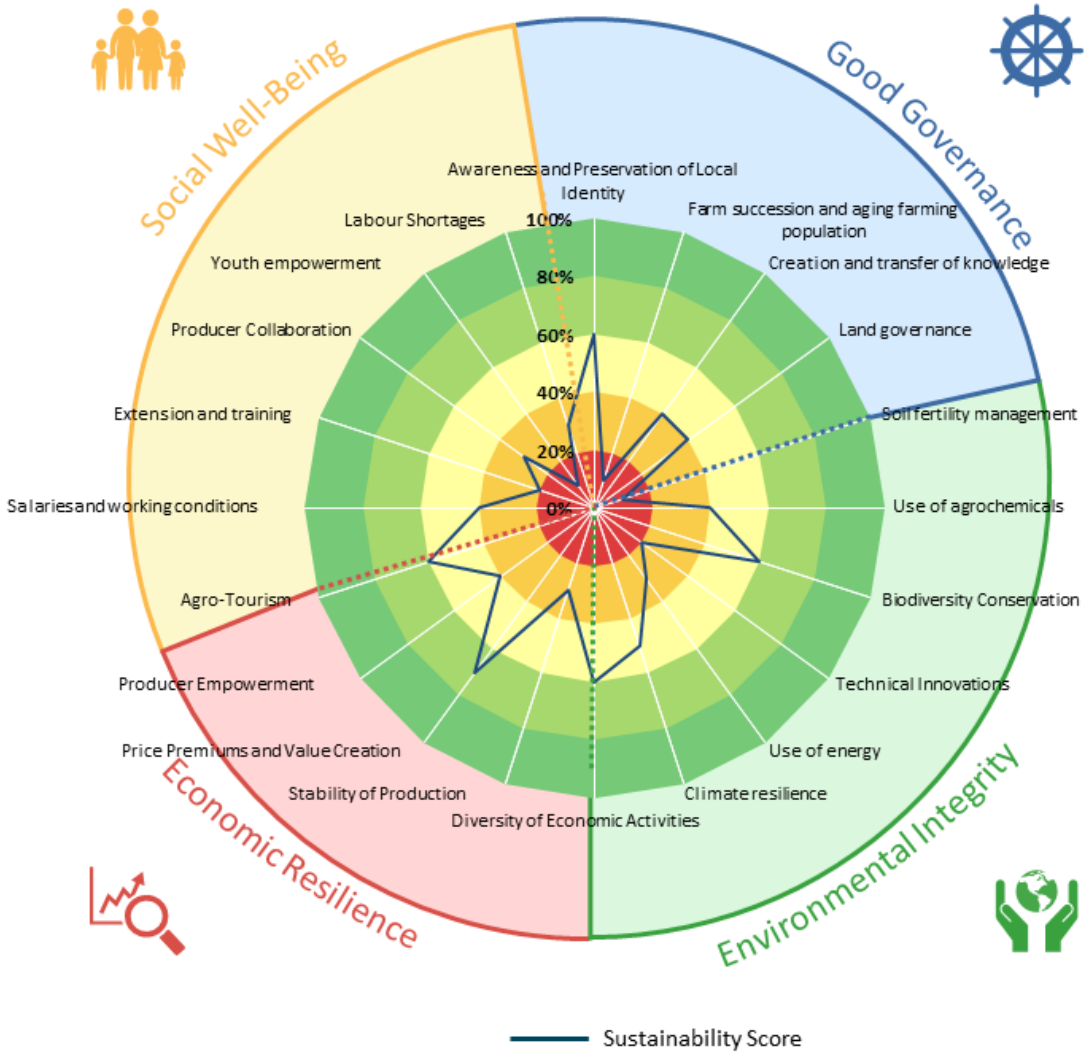

Figure 11: FiBL_Diagram illustrating the sustainability of Pantelleria's farming system divided into 4 components.

If the line stays within the red zone, the score is between 0 and 20% (extremely low sustainability performance). If the line stays within the dark green zone, the score is between 80 and 100% (extremely high sustainability performance).

4.2 Social well-being

4.2.1 Youth empowerment and labour shortages

Rather than encouraging the young to pursue a career in agriculture, the local inhabitants prefer to send their children to the mainland and abroad for lucrative jobs, depriving the island of a future generation of trained farmers and entrepreneurs. In fact, the island faces a severe lack of labour and is confronted with an aging population and a decreasing birth rate, with only a few youths deciding to stay on the island and work in agriculture. This is the reason why some producers are starting to work with migrants on a limited time basis to get more workforce.

As a direct consequence of labour shortages, farming practices are aimed at minimising manual work, with direct consequences on the environment. For example, agrochemicals, especially herbicides, are used abundantly to reduce manual weeding. Labour shortages are directly linked to low salaries.

4.2.2 Producers collaboration

All of the interviewees have expressed the urgent need for new cooperatives and producer organisations to strengthen farmers' bargaining power, access to resources, market opportunities and knowledge sharing. However, interviewees from the Capers Cooperative lamented low interest in the cooperative's financial performance among members and no willingness to exchange and learn from each other. This may be due to farmers' age and their lack of trust in others.

In the past, the island was home to three wine cooperatives, but all of them have failed due to poor management and the lack of collaborative willingness of its members. This is partly why small-scale farmers in Pantelleria have struggled to maintain their bargaining power for the grapes they grow and sell. Today, only the Capers Cooperative has survived, although the number of producers and yields are shrinking year by year.

On the other hand, what is still resisting are the "*circoli*" (clubhouses), small neighbourhood communities that gather regularly to exchange on different topics or organise small gatherings. Each "*contrada*" (quarter) has had its own circolo since the early 1900s. Here, local residents of all ages meet regularly to discuss any pressing topics to the community. According to the interviewees, the farmers that participate usually share farm workloads or exchange favours, but rarely team up as business partners.

4.2.3 Extension and training

The absence of agronomic advisory services and further education opportunities on the island also does not favour sustainable agriculture practices. Most farmers have learned farming techniques from their fathers and grandfathers, and do not integrate modern

best practices into their daily work. Many lack the professional skills and knowledge to farm in a cost-efficient and environmentally friendly manner and do not implement any practices against soil erosion or biodiversity loss. At the same time, the traditional best practices that should be preserved, such as grapevine production in pits, are getting lost across generations.

4.2.4 Salaries and working conditions

Hourly salaries for Pantelleria's farmers abide by government regulations and although not high (amounting to about 1200/1300 euros a month), they allow for a modest lifestyle. However, as previously mentioned, salaries in the construction sector can be twice as high, with an average of 80/100 euros earned per day as opposed to 50/60 earned by farmers.

Grape harvesters are often hired from outside the island as there is not enough local workforce available. Finding enough labour is currently a challenge. On the other hand, Pellegrino and Donnafugata, whose headquarters are on mainland Sicily, usually send in some of their employees for the grape harvest season.

Caper harvesting, on the other hand, still heavily relies on the local workforce, especially women, since the harvest season is much longer than for grapes, and hand-picking capers is traditionally a female-led operation. Despite decent compensation rates for caper harvesting, it has been described as a highly demanding physical activity.

4.3 Economic resilience

4.3.1 Diversity of economic activities

Currently, the economic sustainability of Pantelleria's farming system is a significant pain point for smallholder farmers. Agriculture is no longer an attractive activity for the young. Those who stay, often shift to the construction industry, tourism or the public sector. More and more land is abandoned because it is no longer profitable to grow crops on it.

On the other hand, the 1990s saw an explosion of the construction sector, renovating old "dammusi" or buying former agricultural land to build new holiday homes for well-off tourists. Nowadays, the average Pantescan earns their living by managing holiday homes (often getting paid off-the-book) and, periodically, working on a farm for a few days a month. In a typical household, the husband takes care of the maintenance and gardening of holiday homes, while the wife does the cleaning. This combination appears to be quite profitable for local residents and is a great driver to abandon farming as the main source of income.

Last but not least, the combination of agriculture and tourism (agritourism) is nowadays a widespread business activity on the island. However, transforming old buildings into tourist facilities can be a significant investment that not all producers can afford to make.

4.3.2 Stability of production

In the last years, agricultural production (except that of the large wine producers) has dropped, causing product prices to soar. This is especially true for the Capers Cooperative, which is struggling with financial stability and cannot afford to hire more staff and increase production. With market prices going up, Pantelleria capers are becoming a niche product for those buyers who appreciate the intrinsic value and are ready to pay a premium price. Furthermore, after delivery of the capers to the Cooperative, payments to producers take place after about six months, which jeopardises their liquidity. This inconvenience is an additional reason for farmers to shift to other income sources and to abandon their lands.

4.3.3 Price premiums and value creation

The DOC and IGP certifications for Pantelleria wines and capers have greatly contributed to safeguarding local varieties and traditional farming techniques, as well as strengthening the market positioning of these products. Besides DOC and IGP, organic certification could create further value and improve the overall sustainability of Pantelleria's farming system.

On the other hand, the promotion of local produce by local HoReCa businesses does not seem to be a common trend. In fact, several interviewees have pointed out that many local restaurants and grocery shops do not offer locally produced products and prefer to import these because of lower prices even when they are locally available (e.g capers). In light of this, it is not surprising that no farmer's market exists on the island.

In addition, as discussed before, Donnafugata and Pellegrino hold an unfair advantage over small producers: since their headquarters are on mainland Sicily, they are allowed to sell their produce as Passito or Moscato di Pantelleria DOC even if bottling takes place on mainland Sicily, which drastically reduces their costs. Small producers, on the other hand, are obliged to have their own bottling infrastructures (with their related costs) as per the regulations imposed by the *"Disciplinare di Produzione dei Vini a Denominazione d'Origine Controllata Pantelleria"* (the Regulation of Controlled Denomination of Origin of Pantelleria wine production).

4.3.4 Producers Empowerment

Those who still practice farming, whether full-time or part-time, often do not feel supported by the regional or local government: interviewees have pointed out that taking up bank loans is cumbersome, with frustrating bureaucracy and endless waiting

times. Another hindering factor for those who still wish to work on the land is the high price of water. It has been pointed out that no price facilitation exists for those who need water for agricultural purposes. Tourists filling up a private swimming pool or farmers irrigating crops pay the same amount.

The average hectarage of smallholder farms on the island is about 1.3 hectares. Donnafugata and Pellegrino, on the other hand, control several hundreds of hectares. Their size and influence have allowed them to create a semi-monopoly for grape and wine production on the island, fixing market prices that smallholder farmers struggle to cope with. Concurrently, both wineries offer an opportunity for smallholders to sell their grapes, albeit at low prices.

Unfair competition by large winemakers also appears to be a hindering factor for participatory land governance. The island hosts 12 winemakers, all of whom have voting rights within the "Disciplinare di Produzione dei Vini a Denominazione d'Origine Controllata Pantelleria". However, interviewees have pointed out that Donnafugata and Pellegrino have a much stronger voice in decision-making, which has been creating a lot of discontent among small producers.

Pantelleria's local government is trying to create incentives for farmers to generate more economic opportunities. Among their initiatives, they are currently planning on creating a community winery for people with socio-economic or psychological struggles, which would be funded by Italy's central government. The grapes shall be cultivated with organic methods and farmers will be able to access funding for organic certification for the first 5-6 years. It is also looking into ways to make aromatic herbs in Pantelleria DOC certifiable and to create a community olive mill. However, previous experience with the establishment of community-owned structures has shown that the inhabitants of Pantelleria are little inclined to collaborate.

4.4 Environmental integrity

4.4.1 Soil fertility management

Nowadays, with more and more agricultural surfaces being bought or rented by large wine producers, the island has essentially become a monoculture, impacting biodiversity, soil fertility, and the overall resilience of the island's farming system. Furthermore, because of a lack of manpower and the small size of the cultivation plots, as well as the lack of agronomic advisory or extension services available for farmers, the use of agrochemicals in Pantelleria's farms is abundant. To date, the island counts only five certified organic farms, while the remaining land is cultivated with conventional farming methods.

Up until the middle of last century, animal husbandry was widely practiced. Most farmers kept cows, pigs, donkeys and fowl. Their manure was used as fertiliser and as soil improvement. Today animal husbandry has practically disappeared. This has decreased the amount of organic matter in the soil, leading to a loss of soil fertility and water retention capacity. Nowadays, organic household waste is shipped to mainland Sicily instead of being used as manure in agriculture. Grass and weeds were once considered precious feed when animal husbandry was practiced on the island. Today, grass and weeds are considered a problem that is solved by the frequent use of herbicides.

Intercropping with water-efficient crops such as barley or hard wheat, a centuries-old practice, has almost disappeared. Only a few farms grow leguminous green manures that are rototilled into the soil at the beginning of the vegetation period of the vines or caper plants. Rototilling, however, or any other soil cultivation method with mechanically powered farm equipment, effectively destroys the structure of the soil, reducing its water retention capacity and hampering the penetration of precipitations. Moreover, frequent tilling increases the mineralisation of organic matter, which further negatively affects the water retention capacity.

4.4.2 Use of agrochemicals

Several farms use considerable amounts of pesticides in grape and caper production. Apart from herbicides, fungicides and insecticides are frequently used. Due to their low level of agricultural training, farmers tend to use much more pesticides than what is recommended by pesticide manufacturers, which has serious consequences for product quality, human health, and the environment.

The intensive use of herbicides also jeopardises the ancient practice of growing vines in pits. Cleaning the pits manually from weeds is a labour-intensive practice. Using herbicides requires considerably less labour, but causes the pits to slowly fill up with soil, whereas the advantage of the pits, the collection of dew water and the reduction of evapotranspiration, is lost.

4.4.3 Biodiversity conservation

As Aumeeruddy-Thomas et al. point out (2024), the island has seen a significant loss in agricultural genetic resources (e.g., local wheat and barley landraces and the Pantescan donkey) since the 1830s. A key driver of the abandonment of terraces, agricultural land, and vineyards can be attributed to the emigration of young people and changed attitudes towards crops and animals linked to modern lifestyles and the increased import of industrial products, such as wheat flour.

However, despite the island being almost a monoculture and most farmers using agrochemicals, the fact that 80% of Pantelleria's land has been designated as a National Park has potential for biodiversity conservation.

4.4.4 Technical innovation

For millennia, Pantelleria has led by example in the field of innovative farming techniques to withstand the island's harsh climate conditions. Clear examples of Pantescan efforts are the head-trained bush grapevines and dry-stone walls, which have been granted the UNESCO recognition. However, Pantelleria's innovative thinking seems to have faded over the years.

When asked about "smart agriculture" and the use of drones in particular, no farmer appeared to be interested or saw any advantages. The interviewed scientists acknowledged that warning systems to establish the right moment for intervention with pesticides could be useful. Drones for detecting forest fires in an early stage could also be impactful.

Irrigation would certainly raise yields but the installation of irrigation systems requires high investment and, together with the current price of water, is economically not viable. Moreover, the use of fossil energy to desalinate seawater is hardly a sustainable practice and groundwater reservoirs are non-existent. A functional system for rainwater harvesting could be an option to increase irrigation-water availability but a functional system would require considerable investment.

4.4.5 Use of energy

The need for electrical energy on the island is covered by local gasoline-driven power plants. The required fossil energy carrier is imported from Sicily. Also, the petrol and gasoline used by cars and trucks are imported from the mainland. An ambitious plan to reach the total decarbonisation of the island by 2050 through renewable energy sources called "Pantelleria Zero" was published by Clean Energy for EU Islands, an initiative led by the European Commission. However, the implementation of the plan faces considerable hurdles, even though the island is rich in potential sources, such as wind, solar power and the movement of the sea. One reason for this is that Pantescans, and the Parco Nazionale in particular, fear the disfigurement of the landscape and the loss of biodiversity. In fact, only a very few photovoltaic installations and offshore wind farms are built and functioning.

Concurrently, as mechanisation is almost inexistent in Pantelleria's farms and agriculture still heavily relies on manual work, farming is rather labour-intensive than energy-intensive.

4.4.6 Climate resilience

As previously mentioned, Pantelleria has developed ingenious farming practices over millennia that made agriculture a successful revenue source despite the island's harsh climate conditions. Until today, despite scarce rainfall, crops have managed to get enough water through the humidity captured by ingenious cultivation methods such as head-trained bush vines. However, with the increase in extreme weather events caused by climate change, agriculture in Pantelleria could greatly suffer in the future. In 2021, the island was hit by a tornado which damaged fields and even killed two people. In the same year, the island saw 158mm of rainfall in one night, which is 30% of the amount of rainfall usually seen in one whole year (Comune di Pantelleria, 2021).

The island is also highly subject to fires because of dry summers and strong winds, and the situation could worsen over the next years. Climate change is also bringing new pests to Pantelleria, like the Asian shield bug, which is threatening caper crops.

Concurrently, 400 "Giardini panteschi" were recently surveyed by the University of Palermo as a best practice for climate resilience, due to the water that gets trapped in the circular stone walls surrounding citrus trees (Lega Ambiente, 2021).

4.5 Good governance

4.5.1 Awareness and preservation of local identity

Although there's a high degree of pride when it comes to farmers and their connection with local agricultural traditions, the willingness to drive the island's identity forward seems to be vanishing. Farmers' age is a key reason for this, as well as a lack of trust in authorities, cooperative structures and fellow farmers. Again, this shows that a hindering factor to the sustainability of the island's farming system is strongly linked to mindset. According to most of our interviewees, the Pantescans can be distrustful, envious, and resistant to change. This mentality, among other factors, has slowed down efforts to establish new cooperatives or producer organisations.

4.5.2 Farm succession

Today, Pantelleria's farming system is dealing with several social challenges. One of the most striking relates to the average farmer's age, which stands at 68 years old. The small size of the farms and the low rate of return do not allow e decent livelihood for the next generation. Farm succession is therefore all but guaranteed and many fields are abandoned once the farmers are too old to take care of the land, as is evident in the drastic reduction of agricultural land in the past decades. While the added value upstream of the supply chain is absorbed by processors and traders, farmers are merely suppliers of raw material that receive only a fraction of the sales price of the final product.

4.5.3 Land governance

When it comes to the role of the Pantelleria National Park in creating participative decision-making processes for the island's future, several interviewees have pointed out that few democratic processes are in place to involve residents, although this prerogative is clearly stated in the National Park's statute. Choices made by the National Park are seen as restrictive and top-down, excluding considering farmers' needs from important decisions. During our interviews, several small producers also pointed out that the National Park prioritises the preservation of forests and wild habitats over agriculture, which creates a conflict of interest with farmers.

Finally, yet importantly, interviewees have lamented that with the creation of the National Park, any future attempts to increase agricultural activities will be futile. This is because under the National Park nature conservation policy, any abandoned agricultural land where trees start growing will be designated as forest, meaning that it can no longer be used to grow crops.

4.5.4 Creation and transfer of knowledge

Despite residents not sounding very optimistic when it comes to the socio-cultural challenges faced by Pantelleria's farming landscape, some interesting local initiatives for agricultural education and social cohesion are present and promising. One example is the Università Popolare (Open University), which was founded in 2023 by the personal initiative of a few teachers to empower local residents to learn about Pantelleria's cultural heritage in relation to traditional farming techniques. In the future, seminars will also include social topics, such as the importance of strong collaboration skills for knowledge transfer, mutual learning and a thriving island economy.

Another association called RESILEA has been organising environmental education activities, such as excursions, workshops, or handicraft activities, in order to connect different stakeholders on the island, generate collaboration opportunities and encourage mutual support.

The Vivaio Paulsen, a plant breeding centre headquartered in Palermo with a small branch in Pantelleria, has been studying Zibibbo species for several years and has organised several workshops on Zibibbo cultivation techniques.

To reverse the abandonment of agricultural lands, the Parco Nazionale Isola di Pantelleria is planning to introduce an online info point on agricultural practices, free workshops on grapevine cultivation methods, maintenance of dry-stone walls, and further education in product marketing. The Park is also working with schools to introduce environmental education modules into curricula.

5. Stakeholders' views and perceptions

Our interviews highlighted that most of the small producers and local citizens involved in Pantelleria's agricultural sector were rather pessimistic about the future of farming on the island. The lack of young people interested in pursuing farming activities, the growth of high-end tourism as an attractive income source, the tough competition with the large wineries, a lack of governmental support for farmers as well as a distrustful mentality among producers are all important hindering factors for a thriving agricultural system in Pantelleria.

Despite the aforementioned challenges, interviewees readily shared their hopes and opinions on what is needed for a more sustainable farming system in Pantelleria. The consensus is clear: Farming must become an attractive income source and profession again. Achieving this requires financial, social, and technical support from the government, the National Park, and local businesses, particularly tourist facilities, restaurants, and grocery shops. Trust and collaboration need to be re-established through participatory decision-making processes and mutual support, and the needs and challenges of small-scale producers must be given greater consideration.

The Local Council and the National Park were very excited about the opportunities to revitalise farming on the island. The Local Council, in particular, showed interest in new partnership opportunities to enhance the adoption of sustainable farming practices on the island. Furthermore, the Faculty of Agronomic Sciences at the University of Palermo is actively engaged in research projects on Pantelleria and may serve as a valuable partner for future initiatives on the island. Last but not least, small education initiatives like the Università Popolare di Pantelleria showed much interest in our work and potential future collaborations.

6. Recommendations for a sustainable farming system

The local council and the National Park underlined their strong interest in strengthening sustainable farming systems and increasing the number of organic farmers. To make farming more attractive, we see potential for improvement in all four sustainability pillars: social well-being, economic resilience, environmental integrity, and good governance.

The following recommendations focus on the highest-impact solutions to increase the sustainability of Pantelleria's farming system and thus maintain its attractiveness as a remote Mediterranean island with deeply-rooted traditions and spectacular landscapes. They serve as an entry point for further discussions on how to respond to the aforementioned opportunities and challenges with potential project interventions. Overall, these recommendations match the opinions of interviewees, who included producers, university professors, and members of the local government.

A. **To strengthen Pantelleria's branding as a unique tourist destination. –** The growth of high-end tourism on the island could be seen as a threat to the development of the agricultural sector because it attracts a large number of workers and is a more profitable activity than farming. However, tourism in Pantelleria can also be considered as an opportunity to create synergies with producers and HoReCa organisations and strengthen the local economy. Tourists who travel to Pantelleria are looking for an escape from the hustle and bustle of their daily lives: they seek privacy, peace and quiet, beautiful landscapes, and delicious cuisine. Healthy food grown locally (even better if organic) combined with trekking and wellness activities (Pantelleria has several hot springs) would offer a unique "holiday package" and could strengthen Pantelleria's branding as a niche wellness destination.

B. **To promote the development of stronger producers' organisations. –** Establishing producer organisations in Pantelleria's wine sector will help create more opportunities for farmers and wine producers. Teaming up as business partners and pooling their resources would help them gain greater bargaining and decision-making power while cutting costs and developing joint innovations to strengthen Pantelleria's wine offering and enhance sales. Furthermore, working as part of a group rather than individually would provide better access to financial and technical support as well as capacity development opportunities. Ideally, establishing such groups should be facilitated and supported by the Local Council to ensure optimal outcomes.

C. **To upgrade agronomic advisory services and develop further education and capacity-building opportunities. –** Better access to extension and education in the field of agriculture are vital to promoting sustainable farming practices and encouraging youths to stay in Pantelleria and pursue farming as their profession. Local initiatives like the Università Popolare and RESILEA have already shown promising results in this regard, and new education initiatives could build on the successes of these two organisations to strengthen their offer. The local administration and the National Park are also working on new education initiatives, e.g. the online info point for farming practices and the introduction of environmental education into children's curricula. Yet, this offer needs to be upgraded with more practice-oriented capacity-building offers, as farmers urgently need on-the-field agronomic advisory services. Such education initiatives will help youths engage in career paths that provide tangible business opportunities while making farming practices more environmentally friendly and efficient.

D. **To catalyse partnerships between farmer associations, HoReCa organisations and food retailers. –** A closer collaboration among different actors along the local food value chain would increase the demand for locally and sustainably produced food products. This would bring along significant advantages for local farmers, business owners, and consumers, as the reliance on imports from mainland Sicily would decrease while the sense of pride and appreciation for local products would grow. The support of the local administration and the National Park would be key to facilitating such stakeholder engagement. Along these lines, successful examples of fruitful multi-stakeholder collaborations should also be better promoted to encourage others to follow their example. Here, the "circoli", AGRILEA and the Università Popolare di Pantelleria are success stories to learn from.

E. **To establish a "centralised" bottling infrastructure. –** A sole, centralised bottling infrastructure in Pantelleria would ensure that the whole value chain of Zibibbo wines would be located on the island—with no exceptions for large wineries. This would strengthen the "Pantelleria branding", i.e. help reduce costs for small producers and make them more competitive versus the large wineries. For this initiative, the financial support of the government and the National Park would be vital.

F. **To support the conversion to smart and organic farming. –** Co-funding smart technologies that reduce labour demand or covering organic certification costs during the conversion period would improve the sustainability of the farming system without imposing a financial burden on farmers. The introduction of smart technologies must be handled with great sensitivity through careful consultation with local farmers and agronomists. This approach would ensure respect for local traditions and farming practices while supporting UNESCO heritage and quality certifications (i.e. DOC wines and IGP capers) without causing any disruptions. At the same time, organic farming would preserve Pantelleria's unique mix of man-made and natural landscapes and ancient farming techniques. It would allow soils and biodiversity to regenerate and provide a market premium to farmers. In this regard, the Local Council is looking into available subvention schemes from the central government and the European Union.

G. **To implement an organic waste collection centre and processing plant. –** Rather than hauling organic household waste to Sicily, an organic waste collection and processing plant should be considered for Pantelleria. This would create new jobs and would allow farmers to access highly valuable organic waste

as compost or biogas sludge. Such "nutrient recycling plant" would help improve soil fertility, which is currently an important challenge for Pantelleria's agricultural production system. At the same time, this measure would avoid unnecessary shipping costs and greenhouse gas emissions.

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