D3.3 IA 2.2 brief: Economic efficiency gains from new value chain solutions to stimulate the uptake of fire-preventive measures and reduce losses from wildfires

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Abstract: This deliverable explores economic efficiency gains from new value chain solutions aimed at stimulating the uptake of fire-preventive measures and reducing losses from wildfires in Mediterranean regions. It covers two main analyses: one on prospective orchards on forested areas, and a second on innovative mechanization. Focusing on the southern Pyrenees and Pre-Pyrenees, the first analysis examines the integration of vineyards and apple orchards as part of a landscape-level wildfire mitigation strategy. These woody crops create productive firebreaks while revitalizing rural economies through diversified agriculture, cooperative marketing, and enotourism. The second section evaluates innovative mechanized silviculture systems for managing fuel loads in forested areas of Catalonia (Spain), Tuscany, and Sardinia (Italy). Field demonstrations show that multifunctional, lightweight forestry machines (intended as timber harvesters and forwarders) can significantly reduce operational costs, up to 45%, compared to traditional methods (commonly performed with chainsaw and farm tractor), while improving safety and efficiency. The last section provides a strategic approach to secure the resilience of the local value chains based on timber products. Together, these approaches present scalable, economically viable models for fire-resilient land use that align environmental stewardship with socio-economic development.

Key words: Wildfire prevention, Bioeconomy value chains, Woody crops, Mechanized silviculture, Rural development.

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Acronyms

DO: Designation of Origin

EAP: Equips d'assessorament i orientació psicopedagògica

HNVF: High Nature Value Farmland

IA: Innovation Action

LL: Living Lab

PMH: Productive Machine Hour

RVC: Registre Vitivinícola de CatalunyaSIEX: Sistema de Información de Explotaciones Agrarias

1. Introduction

This deliverable investigates economic efficiency gains from innovative value chain solutions designed to enhance the uptake of fire-preventive land uses and reduce wildfire-related losses in Mediterranean regions. Building upon the insights from the Innovation Action 2.2, it evaluates both the technological and financial dimensions of wildfire mitigation, focusing on three key components: the strategic deployment of agricultural woody crops, the mechanization of preventive silvicultural operations and the resilience of timber value chains in the frame of wildfire prone landscapes.

The first section of D3.3 examines the socio-economic feasibility of integrating of vineyards and apple orchards into forested and mountainous landscapes as productive firebreaks. By revitalizing rural economies through diversified agriculture, cooperative models, and value-added activities like enotourism, these land uses contribute both to fire resilience and socio-economic development. The financial indications presented here draw on empirical data to assess profitability and feasibility, offering practical guidance for scaling up these land-based solutions.

Following the document provides a foundational cost analysis of improved wood mechanization techniques, demonstrating their capacity to reduce overall costs, by up to 45%, and improve safety and efficiency in fuel load management. These advancements support the economic viability of sustainable forestry practices essential for wildfire prevention.

Finally, it provides a strategical approach to secure the whole forest based value chain in territories with high wildfire risks. This analysis aims at providing the needed resilience to the whole economic sector, making it able to absorb the impact of wildfire losses in timber procurement (raw materials) guaranteeing the continuation of the rural and industrial work based on the local forest resources.

Together, these findings illustrate how synergistic approaches, combining technological innovation with land use diversification, can enable cost-effective, socially inclusive strategies for building fire-resilient territories.

1.1. Technology Readiness Level

The Technology Readiness Level (TRL) progress of the IA2.2 is not a unique value. In fact this Innovation Action and the related deliverables are a summary of different and complementary research and development activities, each featuring its starting and final TRL.

The detailed description of the TRL evolution along the project's progress for each innovation in IA2.2 is reported in D2.2, which features the technical description of the work done. The present D3.3 reports the economic results of each technology solution to cope with with wildfire risk. As such, it does not entail differences in terms of TRL compared to the previous deliverable.

2. Objectives of the deliverable

The objective of this deliverable is to analyse economic efficiency gains from new value chain solutions in wildfire-prone regions, particularly in the Mediterranean. Specifically, it aims to:

1. Assess the viability of integrating woody crops like vineyards and apple orchards into fire prevention strategies (chapter 3).
2. Identify socioeconomic and legal constraints in adopting these crops within forested or mountainous areas (chapter 3).
3. Demonstrate cost-effective, mechanized solutions for silviculture to manage fuel loads efficiently (chapter 4).
4. Stimulate the adoption of fire-preventive land use by showcasing successful implementation models that support rural development and ecological resilience (chapter 4).

3. Economic, legal and social data gathering and analysis for fruit crops for fire prevention

3.1. Introduction

The objective of Task 3.2.2 (Bioeconomy value chains) is to seek for innovations in traditional and mountain fruit production for maintaining a mosaic, by analysing the economic sustainability of introducing or recovering woody crops amidst forest using agricultural management techniques that allow to optimize the reduction of inputs, increase production efficiency and ensure production in sufficient quantity and quality, to allow an active and sufficient life of the population, while reactivating the binomial crop-forest (linked to IA 2.2). It will concentrate in vineyards and apple orchards. On one hand, grapevines are a crop with a high added value (for wine production) and in search of new production areas (even in new countries or regions) as adaptation to climate change, but on the other hand it has many regulations. Apple production is not so regulated as winegrowing and can have an interest in many other non-Mediterranean countries.

Deliverable 2.2 (D2.2) IA brief 2.2: Scheduling and implementing novel management practices (Busquets et al., 2024; Section 2) provided suitability maps for two woody crops (vineyards and apple orchards) in mountainous regions in the central-west region of the Southern Pyrenees and Pre-Pyrenees. Those could give an example of the range of possibilities to strategically introduce HNVf solutions in mountainous regions to reduce wildfire areas. Moreover, suitability maps were overlapped with the results from the IA 2.3 to better specify where those woody crops could be planted to enhance landscape resistance and resilience against wildfire events. Finally, main socioeconomic limitations to develop the farming activity were also identified and summarized. Although an initial approach to socioeconomic constraints are identified in D2.2, a further explanation on this specific topic is developed in this present deiliverable.

Within the working framework of this deliverable (central-west region of the Southern Pyrenees and Pre-Pyrenees; Figure 2) there are two different situations depending on the crop studied.

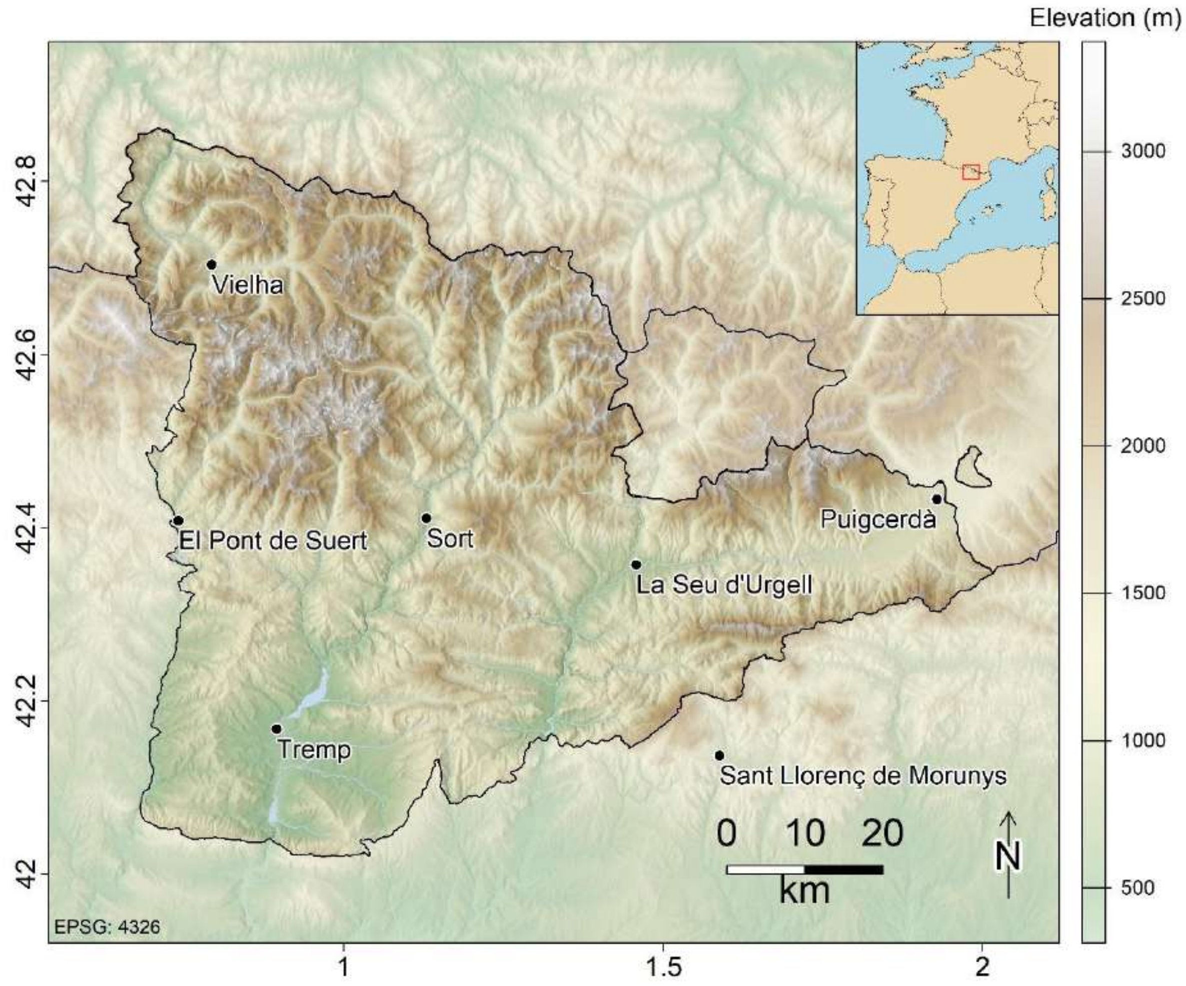

Figure 2 Study area location with the main population centers.

As for vineyards, the first important plantings date from 1998 on an approximate surface of 8 ha at about 930 m (Sant Miquel de Tremp, Tremp) which has been expanded over the years until reaching 90 ha, owned by a company in the sector. In 2001, another company started operating in a nearby area (Castell d'Encús, Tremp) at between 800 and 950 m. Since then, several small-scale private initiatives have been emerging, both by farmers than in the past they (or their family) had worked themselves to the cultivation of the vineyards (some even still kept small cellars in their farmhouses) as others who had no connection with it. Data published in 2022 show an approximate coverage of 314.01 ha of vineyards planted in the study area at heights between 376 and 1,471 m (SIGPAC, 2022) as shown in Figure 3.

Apple orchards, on the other hand, started in 2009 with the establishment of an observatory and experimental field of apple trees in the village of Llesp (El Pont de Suert) (Iglesias et al., 2020). It was a pioneering initiative in Spain, since there were no references for this crop in mountain areas close to 1,000 m altitude. The evaluation of the different varieties began at the Llesp farm, located at 980 m, with the planting in March 2009 of 15 commercial apple varieties. The objective was to evaluate their adaptation to altitude on the basis of productive behavior and fruit quality (instrumental and sensory). With the results obtained and considering the planting costs, the viability as a productive option was subsequently evaluated, which resulted in the first commercial plantings in November 2012. Since then, apple cultivation has gradually expanding to different localities in the Eastern Pyrenees. Data published in 2022 show an approximate coverage of 93.30 ha of apple orchards planted in the study area at heights between 419 and 1,378 m (SIGPAC, 2022) as shown in Figure 3.

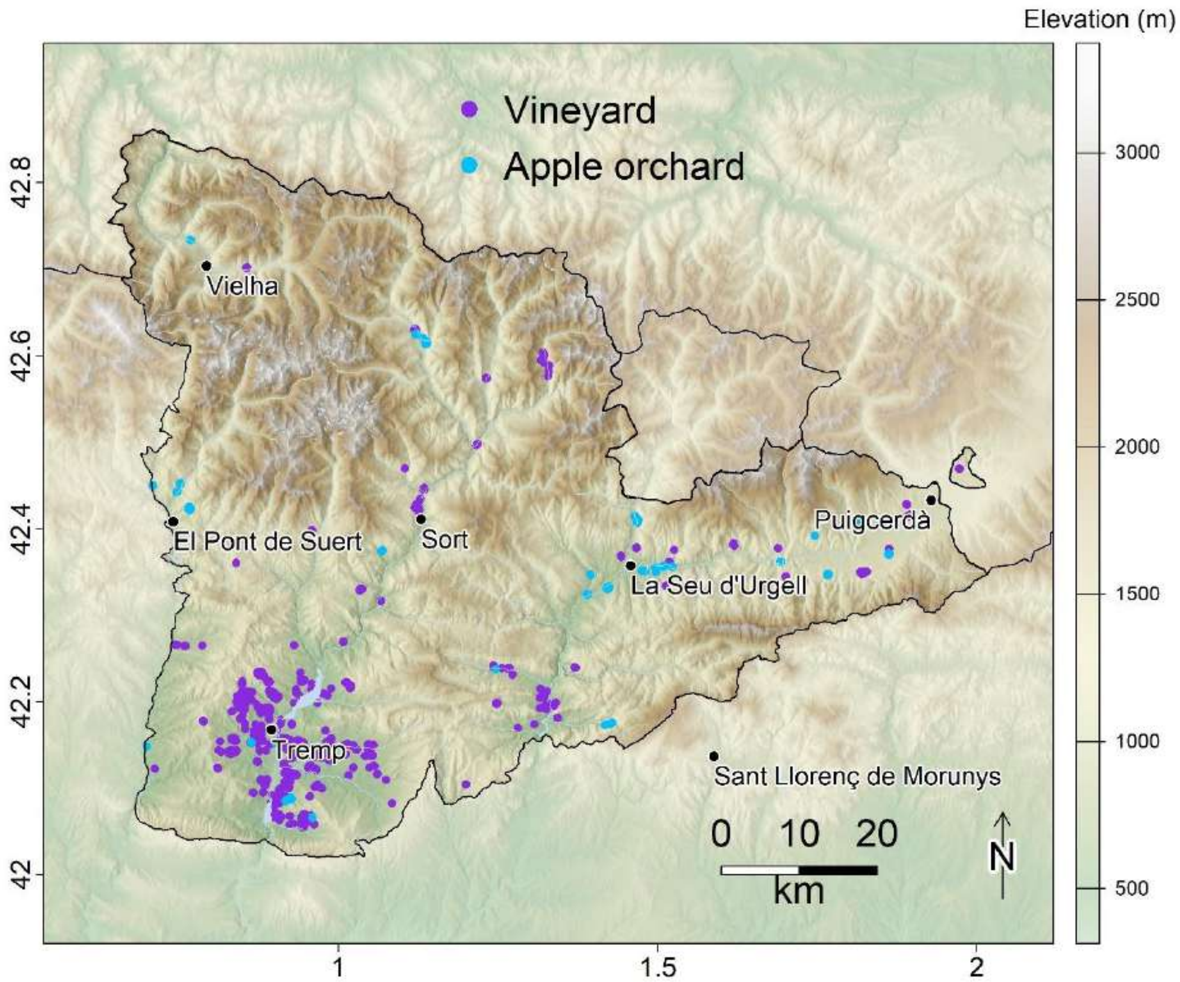

Figure 3 Vineyards and apple orchards from the study area (DUN, 2022; SIGPAC, 2022).

The high-altitude plantations carried out to this day generally respond to two exploitation models: the first corresponds to consolidated companies in the fruit sector located in the areas of traditional cultivation that diversify their production. In this model, the companies already have their brands and their own commercial circuits for both national and export markets. The second model corresponds to that of small owners of farms, usually disused or given almost altruistically to the last cattle breeders present in the various mountain areas, where cattle breeding has always been a traditional activity linked to the territory, but which is in clear decline. In this case, these are small plots of land close to the towns and which generally have irrigation water, good accessibility, with optimal soil conditions and a good aptitude for the production of grapevines or apples. The owners engage in part-time production, as a complementary activity and income. It is a marginal activity, many times as a second economic activity, that local producers in the area have started to diversify their production or as an alternative to exploiting land they own. Due to the smaller dimensions of these plots and the lack of connection with pre-existing commercial circuits, this type of production is focused on local markets that are able to value this type of quality, local and linked production to the territory and its economic development. In the specific case of apples, to improve their distribution chain, a group of these small owners created the Biolord mountain apple association in 2012.

Despite data is available on the evolution of both vineyards and apple orchards in mountainous regions thanks to the annual agricultural records, there is a lack of information regarding the socio-economic factors linked to these types of farms. There is no collection with the implementation and maintenance costs that these plots may have, as well as the main obstacles that can be encountered when trying to implement them. Although the companies already established in the sector can have a more detailed study of the costs associated with this type of productive activities, most farms, of a private nature, respond to situations that are very different from each other and have associated costs of very different implementation. For this reason, if it is intended to encourage this type of activity to generate a landscape mosaic in mountainous regions, a study is required in order to collect the experience of all those people who for years have carried out agricultural activities linked to woody crops in these areas.

3.2. Objective

The objective of this section 3 is to provide clear insights about economical and social limitations for woody crops activities in mountainous regions, specifically for vineyards and apple orchards.

3.3. Material and methods

The study is composed by two methods with the objective to identify the main socioeconomic constraints for grapevine and apple production. Startin with surveys towards farmers with vineyards or apple orchards plots and/or wineries from the study area of D2.2 Section 2 (central-west region of the Southern Pyrenees and Pre-Pyrenees; Figure 4; Busquets et al. (2024)) and Sant Llorenç de Morunys (outside of D2.2 Section 2 study area but included herein due to its proximity and importance in mountainous apple production). Socioeconomic surveys were designed to extract information both from the experience of the farmer towards the activity and from an economical point of view. On the other hand, a review of limiting factors linked to legislation was performed to identify the principal constraints when seeking to start a new plot, specially if its located in a forested area.

To extract all the necessary information for each of the farms, the socioeconomic survey was divided into two parts. Firstly, a series of questions were asked in order to obtain a general idea of the context of each of the farms and the personal experience of socioeconomic problems (Annex II. Socioeconomic survey).

This survey begins by exploring participants' personal experiences with socio-economic challenges in agriculture. It examines issues related to accessing land, including average plot sizes, difficulties in acquiring larger plots, and the availability of land markets. Respondents are also asked about assistance programs for young farmers and tools that could address access barriers. Further, the survey investigates challenges in maintaining continuity in agricultural operations, such as barriers to succession or lack of heirs, and considers the broader impacts of rural exodus. Participants are invited to reflect on farmland abandonment trends, and the potential of vineyards and apple orchards to retain populations in rural areas. They also evaluate a range of socioeconomic factors that affect their operations, such as competition for land and water, labor shortages, market pressures, problems with wildlife, and disruptions in supply chains. They are asked to highlight the factors causing very serious troubles while developing the activity. Lastly, the survey examines the availability and effectiveness of support tools, such as cooperatives, training programs, and financing mechanisms, that contribute to making agricultural activities more viable and competitive. Participants are encouraged to highlight their main challenges and suggest improvements. These responses aim to identify barriers to success and offer practical solutions for overcoming them.

Secondly, a series of tables with costs and benefices (Annex III. Economic survey – Vineyard and Annex IV. Economic survey – Apple orchard) designed to gather comprehensive data on the economic aspects of managing and orchard in full production during an average or normal year. It focuses on collecting information critical for understanding the costs associated with operations and their underlying socioeconomic context, enabling an in-depth analysis of financial requirements. The first information gathered is general about location, irrigation and planting conditions, as well as the usage of the main product and how the orchard is managed. After the contextual details, the production information is asked as for yield and bottle production (in the case of vineyards). The labour salary for the different workers of the exploitation is also gathered for a better understanding of the task force needed to run the plantation. As for fixed costs, different topics are treated firstly asking for land adquisition or renting, then for structure (poles, wires, nets, anti-frost measures, etc.), plantation (soil preparation, plants, tutors, services, etc.), machinery (adquisition, maintenance, etc.), irrigation (study, distribution network, etc.) and cellar machinery in the case of vineyards (press, deposits, etc.). For operational costs the table gathers structural (maintenance and reparation, other tasks, etc.), soil management (plowing, sowing, mulching, etc.), plants (pruning, harvesting, transports, etc.), fertilization and other treatments (herbicide, fungicide, etc.). For wineries, there is also and additional table related to specific winery costs like material (bottles, cork, boxes, etc.) and vinification tasks (enology services, winemaking tasks, etc.). As for infrastructure, the cost of different sources of energy is asked (electricity, fuel, gas, etc.), water, transportation, commercialization and security (alarms, fence). Finally, there is also a table with insurance costs, certification or consulting.

3.4. Results

3.4.1. Interviews

For vineyards, from 20 farmers found, 10 were interviewed and 10 did not participate in the study, due to non-answer (3), non-interest (1), inhability to meet (3), or ceasement of the activity (3). For apple orchards, from 20 farmers found, 7 were interviewed and 13 didn't participate, due to the small size of the plot (5), non-answer (2), non-interest (2), inhability to meet (3), or ceasement of the activity (1). A summary of the participation in the interviews is presented in Table 1 and Figure 5.

Table 1 Summary of the interviews participation.

Crop	Identified	Performed	Not performed				
			Non-answer	Non-interest	Inhability to meet	Activity ceasment	Plot too small
Vineyard	20	10	3	1	2	3	0
Apple orchard	20	7	2	2	3	1	5

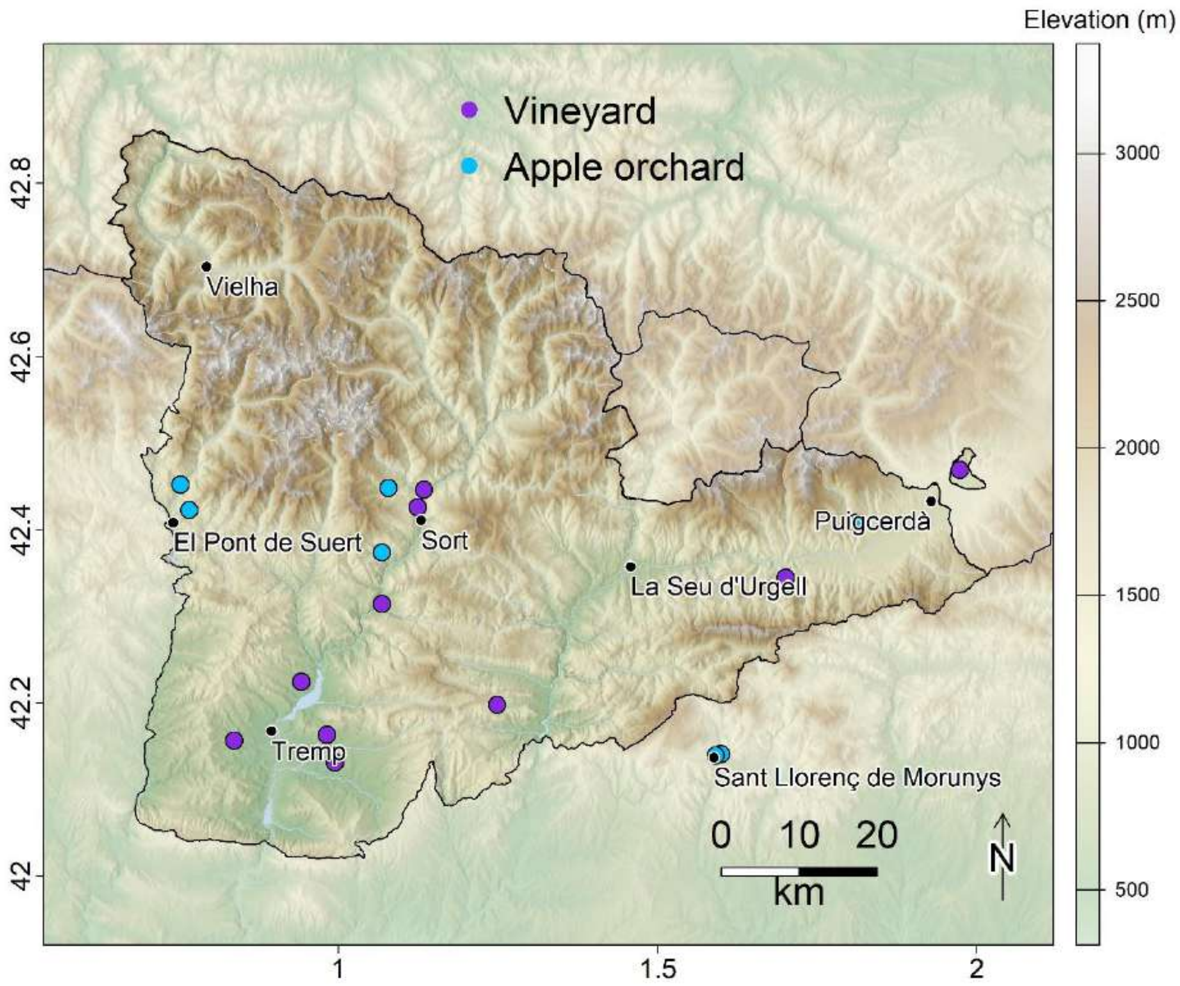

Figure 5 Interviews performed for each crop.

3.4.2. Interviewed farms characterization

Vineyards show considerable variation in terms of the year of planting (Figure 6), with the oldest being in 1999 and the most recent in 2018, and without a clear pattern in terms of how these plantings have occurred. We found them distributed throughout the entire period between 1999 and 2018, with some from 2002, as well as from 2008, 2011 and 2015. The fact that there was no pattern in terms of the years of planting of the different farms indicates that these respond to isolated private initiatives, in this case all of a local nature and on a small scale, without having a cooperative relationship between them. However, from the interviews it was possible to extract that several of them have took the example of those that had already been implemented previously, seeing that these worked. In terms of altitude, the highest ones are located from 1,100 m (1,233, 1,150 and 1,120 m respectively), and the lowest around 600 m (603 and 614 m), being the one with least altitude of all a plantation at 551 m. The height at which we found vineyards also does not respond to any pattern of use, such as seeking certain heights to obtain a better product. Most of the farms are planted in familys' lands that owner posses or in the other case farmers seek to rent some near their municipality. The plantation area is also very variable (Figure 6), with some that could be considered large in relation to the type of vineyards found in mountainous regions (13 and 10 hectares) and others of smaller and minimal size (0.8 the smallest and around 2 ha the rest), with farms of intermediate size between the range (around 6 – 7 ha), accumulating a total of 51.3 hectares of vineyards between all the farms.

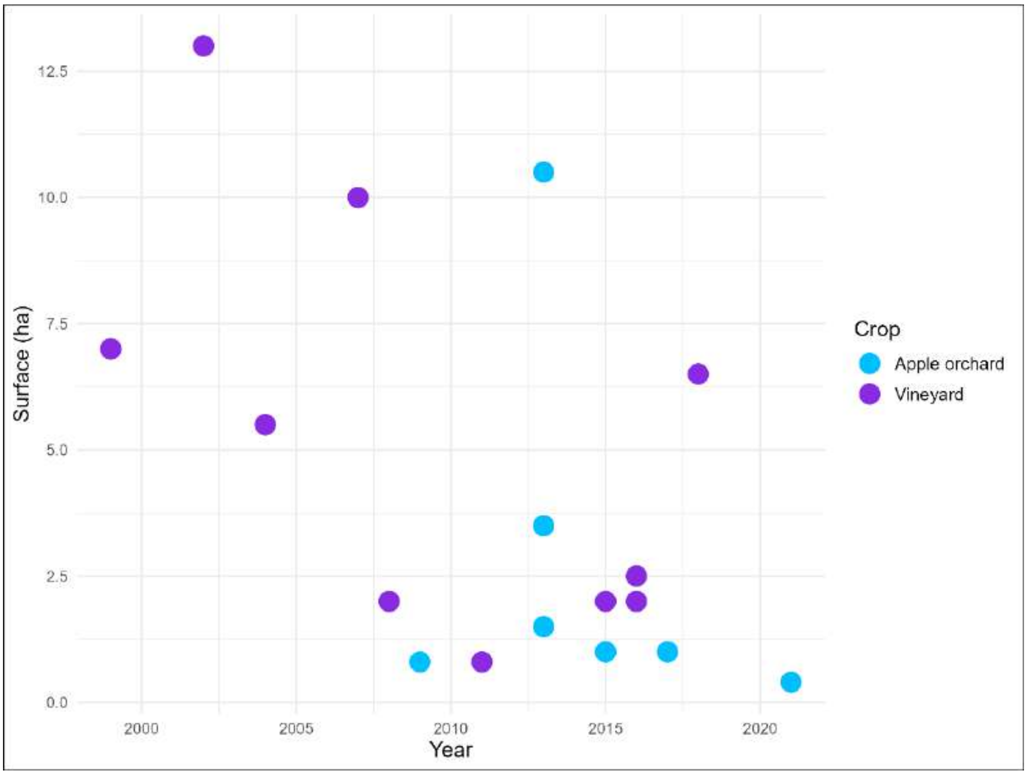

Figure 6 Surface and year of plantation for each orchard interviewed.

The plantation density in some cases remains very similar at around 4,000 plants per hectare, but in others it is chosen to introduce greater spacing between the rows and/or between the plants, obtaining a lower density that is around 2,500 plants per hectare. Production (Figure 11) is generally balanced at around 4,000-5,000 kg per hectare, with maximum values of 5,500 kg per hectare but we also found lower ones around 3,000 kg per hectare and decreasing to 2,000 kg per hectare. Plant density and production are certainly related. In general terms the higher plant density, the lower the yield because of resources availability per plant is lower. But climate variability between sites and years can be much more influential on yields. Also, the grape quality objectives can determine the vineyard design and management to force higher quality with less yield. For example, farms with what could be considered a low production (2,000 kg per hectare) are kept low expressly for the type of wine they want to obtain and the philosophy of the operation. Some production data, also for those where only part of the farm is productive, are not updated since the property does not fully account for what it extracts from each plot and although some values could be provided, these would possibly be very biased and would be unrealistic.

Most of the plots did not have any irrigation method available, although some of them did this installation (but without use during the production process). The latter have it to provide the plantation with an irrigation infrastructure both to ensure the necessary water during the first years after planting and in case of drought episodes that could compromise the production or survival of the vineyards. Although irrigation is not implemented in many plots, it has been carried out (and is recommended) during the first seasons after planting. It has been common in several to lose more than half of the plants due to lack of water during the summer months. The fence against wild fauna, on the other hand, is considered a more essential element for the protection of crops, especially those plantations close to wooded areas, and only three of the farms do not have any protection measure and a fourth uses a mobile one (electric fence) that is installed at the time of the harvest. The rest of the vineyards do have a fixed fence, either of mesh, synergetic or electric sheperd that is always installed.

Finally, it is important to take into account whether the farm has a cellar where the grapes produced can be vinified. In many cases, this infrastructure is present (70 %), but there are other producers who, due to their particular conditions, decide to vinify their product in an external cellar (30 %). Many of the farms are currently owned by the farmer (80 %; Figure 13) and only two are currently rented. These rentals, however, do have a 25-year contract, a time considered sufficient to amortize the plantation. Having a cellar is very important both for the implementation costs (which increase them the most) and for the management of the product. The existing farms, with the exception of part of the production of two of them, are not dedicated to the production of grapes for sale to cooperatives (which do not exist in the area) or to large companies (only in the Tremp area). Although this form of business does exist and is carried out by some of the farms visited, the quantity they sell is decreasing and some of them have even considered completely uprooting the plots used for direct sales because they are increasingly less profitable. The price received for the grapes is decreasing and the production costs are increasing. Farmer from V4, with a family business that previously only worked towards producing grapevines for selling said that "*there are farms that have directly uprooted the vines to re-lease them to extensive farmers. We will possibly in the not too distant future end up uprooting some hectares and will only keep those that we can manage for winemaking. What they pay now is no longer worth it. Here, on top of that, transportation and production cost much more than the price recieved*". In addition, the differentiation that exists with the final product (what could be considered mountain wine) allows a much more profitable sale than what can be obtained in exchange for the grapes, even if we take into account prices from a few years ago. For this reason, the destination of the grapes in the vast majority of farms is for winemaking itself and it is here that the fact of being able to have or not having an infrastructure where it can be done on the farm itself becomes important (Figure 7).

Figure 7 Cellar implemented in an existing building near the vineyard.

Several factors play a role in the cost-benefit balance for setting up a cellar. The main negative aspect is its cost, since if you do not have even an infrastructure (Figure 8) where you can house it, the expenses can climb to 565,000 € for a winery that can manage around 15,000 bottles per year (Table 3). The large amount of bureaucracy required can also be a setback, but it is not an obstacle if the business idea includes the construction of the cellar. As for the positive side, the fact that the winery itself can become the main point of sale and advertising for the operation is particularly noteworthy. Many farmlands try to take advantage of this investment to carry out wine tourism (enotourism), tastings and have a shop in this same space, this being the main way of connecting with potential consumers. In this way, not only is an experience offered that is combined with the sale of the product, but in addition, a direct sale of the same is made, achieving a better price than through commercial distribution channels. On the other hand, the fact of not being able to manage the product on the same farm entails several disadvantages.

Figure 8 First steps of a cellar under construction for both vinification and enotourism experience.

First, a space must be found where the grapes produced can be vinified, but it must also be ensured that in this space, if the producer does not have access to the fermentation, the processes are carried out following the guidelines established by the producer in order to obtain the desired final product. Secondly, since it involves a transport, which in some cases exceeds 150 km, both a refrigerated vehicle must be available to transport the grapes and personnel at the time of harvest to minimize trips back and forth from the cellar to the farm. The production is also more expensive, since not only do the farmer end up paying for the raw material for the winemaking products and bottles, but must also add the costs of services for the winemaking. As a counterpoint to these drawbacks, it could be justified that the volume of work is significantly minimized, since once the grapes are delivered for winemaking, the farmer only have to wait to receive the finished product, so it can become a good option for those people who do not have the investment capital for a winery or who do not have enough time or knowledge to carry out the winemaking process.

Regarding the origin of the property of vineyards, half of the cases come from family farms and the other half from purchases made expressly for growing vineyards. The purchase prices were between 5,000 € and 10,000 € per hectare, although the year of acquisition must be taken into account, since currently the price is probably much closer to 10,000 € than 5,000 €. The rentals for which the price is recorded is around 800 € and 1,375 € per year and hectare. All the people consulted agree that it is necessary to have ownership of the land as it is a sufficiently important investment to do so under rental conditions, also thinking about the possible continuity of the activity. If the construction of a winery is considered, the rental, even in 25 years, can become a problematic situation since both the primary activity and the winery itself revalue the land and conflict could be created regarding renovation. Farmer from A2 said towards this regard that "*Personally, I would not do a project of this nature, where so much infrastructure needs to be built, on land that was rented*". Ownership provides security, but it involves an investment that is linked to the availability of a market for plots. The existence of this market is what determines the establishment of new farms, since in many cases it is non-existent. Through the survey, it was possible to confirm how the main problem with starting activities is the fact that owners are not willing in many cases to sell plots and, in the same way, are reluctant to establish long-term leases (such as 25). However, it can be seen that the activity is attractive enough for several individuals to proceed with the search and purchase of plots to develop a wine-growing activity.

As for the practices, there are four cases of organic farming, of which three are certified, and one is regenerative. The other four, although trying to apply organic farming criteria and minimizing inputs to crops, follow a more conventional management method.

In apple orchards (*Table 2*), the most recent implantation of this crop in the mountainous region of study can be observed (*Figure 6*), and as these respond to the demonstrations that were carried out by Iglesias et al. (2020). From this, a series of private and small-scale initiatives arose trying to replicate both this experience and the methodologies of the

Italian Alps. Cooperativism materialized with the creation of Biolord (https://biolord.cat/), an association of mountain apple producers who from the beginning came together to jointly market their product using a joint brand and share the costs of advice, storage and distribution. Except for the demonstrative apple orchard, planted in 2009, all the rest date from 2013 onwards. The height of the plantations (*Figure 6*) is around 1,200 m of those that can be found at higher altitudes (1,348 in the case of the highest and 1,221 m and 1,191 m in the subsequent ones) and does not decrease from 800 m to the lowest (minimum around 820 m). The height of the plantation shares a precedent that could be considered identical to that of the vineyards, where farmers end up planting on their family farms or looking for the ones closest to their home. The plantation surface in a single case approaches 10 ha, all the rest are located around 1 ha with the exception of one of 3.5 ha. Plantation areas are generally low (*Figure 9*) on the one hand given the secondary role that this activity has within the dedication of its owners and on the other hand due to the difficulty of accessing the land, causing people who would like to increase plantations to encounter many obstacles when obtaining plots relatively close to the current one.

Figure 9 Usual size of apple orchards (around one hectare) in mountainous regions, with between one to three plots per farmer.

On the other hand, a plantation that we would consider large (within the territorial area of study) stands out, which does constitute the owner's main activity and is also established in association with a large company in the sector in traditionally cultivated areas (*Figure 10*).

Figure 10 Biggest plantation in the studied area, of around ten hectares in total.

In terms of plantation density, the farm with 750 plants per hectare stands out, which is the only extensive model of all those interviewed, with the plants much more spaced apart than the rest. Generally, it is obtained with about 2,000-3,000 plants per hectare. In terms of production (*Figure 11*), we do find many differences, between 40,000 and 15,000 kg per hectare. Since new apple plantations are generally based on a model and are usually advised by the cooperative, the planting frameworks are much more similar than in the case of vineyards, where each farmer obtains different options depending on their objectives, type of wine to be produced and management. The productivity of the apple, therefore, and knowing its antecedents, would be expected to be much more equitable between farms than that obtained in reality. It is important to highlight the caliber in this factor, since it is important in terms of marketing. Very different productions generally involve fewer calibers A (the best valued by the market) and a greater proportion of types B and C). On the other hand, the management of apple at height is not easy due to late spring frosts and the alternation that these episodes, and others, can generate.