

## Article

# Specialisation, Fragmentation, and Income Instability in Emerging Hop Production Systems: Microeconomic Evidence from Italian Farms

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## Abstract

The growth of the Italian craft beer sector has renewed interest in domestic hop cultivation, presenting a promising opportunity for farm diversification, despite challenges such as structural fragmentation and limited economic data. The study examines the structural and economic characteristics of Italian hop farms using harmonised microdata from the Farm Accountancy Data Network (FADN) for the years 2021 to 2023. The sample includes 13 farms (selected from an initial sample of 14 after outlier detection) with 32 validated farm-year observations, representing approximately 19% of Italy's total hop-growing area. A multivariate analysis—combining Principal Component Analysis (PCA) and fuzzy C-means clustering—was performed using five key economic indicators: gross margin (GM), variable costs (VCs), hop production (Q\_HOP), specialisation ratio (SH), and the coefficient of variation in the gross margin (GM\_cv) as a proxy for income stability. The results identify three distinct farm profiles: (i) resilient specialised farms with high margins but significant income volatility; (ii) intermediate emerging farms; and (iii) diversified units where hops represent a secondary crop. The findings of this study provide an in-depth understanding of the economic strategies underpinning hop cultivation in Italy, which may be of interest to all organisations where hops are grown as an alternative crop. They offer concrete guidelines to policymakers to support the sector's development through targeted measures that address issues relating to farm size, technical capabilities, and supply chain integration.

**Keywords:** hop cultivation; hop farm typologies; fuzzy clustering; gross margin analysis; Farm Accountancy Data Network; Principal Component Analysis; supply chain integration



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## 1. Introduction

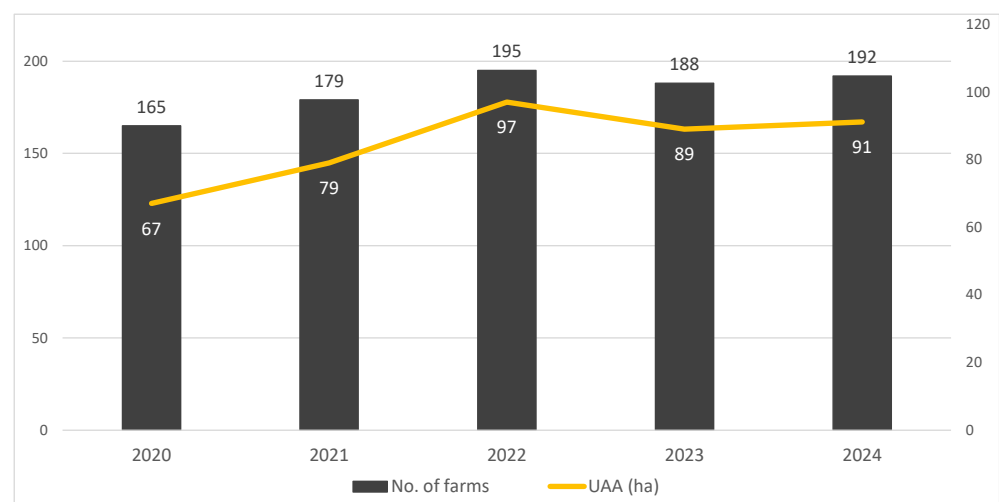
In recent years, rising demand for craft beer [1], combined with a growing preference for short agri-food supply chains [2,3], has transformed hops (*Humulus lupulus* L.) into a strategic option for farmers seeking to diversify their income [4]. While hop cultivation was traditionally a marginal activity in the Italian agricultural context, it has recently gained significant traction. This shift is largely driven by a consolidating domestic beer market and a new agricultural policy that encourages multifunctional farming [5].

Historically, Italian breweries were almost entirely dependent on imported raw materials [6]. However, the adoption of Legislative Decree 75/2018 served as a major turning

point, formally recognising hops as a cultivable crop and opening new opportunities for farmers, including the development of innovative business models. The rising appetite for Made in Italy products offers breweries a unique chance to strengthen their territorial branding by using exclusively national ingredients [7]. Beyond simple marketing, this shift reinforces the entire value chain by creating tighter links between producers and processors, which in turn bolsters local economic resilience. For farms, this expanding demand provides entry into a high-potential niche market, allowing them to keep a larger share of value within their own communities. The ultimate goal of these efforts is to build a robust national supply chain for a material that has long been sourced from abroad.

Despite this optimistic expansion, the sector still faces significant hurdles, including structural fragmentation, a lack of technical expertise, and an underdeveloped market organisation. Crucially, our empirical understanding of the economic and structural profiles of these farms has not kept pace with the industry's growth. Without concrete, farm-level data, it remains difficult for policymakers to design effective support measures or for farmers to accurately judge economic viability. High entry barriers, such as installation costs ranging from €16,000 to €20,000 per 0.5 hectares (ha), further complicate the pursuit of economies of scale.

Nevertheless, the domestic sector continues to grow. Data from the Italian Agricultural Payments Agency (AGEA) show that the national hop-growing area rose from 67 ha in 2020 to 91 ha in 2024, involving 192 farms with an average size of approximately 5000 m<sup>2</sup> (Figure 1). Cultivation is currently concentrated in northern and central Italy regions like Emilia-Romagna, Veneto, and Piedmont, which accounted for over 54% of the national area in 2023 due to favourable pedoclimatic conditions [5,8–10]. While southern regions face more agronomic constraints, climate change is leading some farmers there to experiment with hops as a resilient complementary crop [11,12]. Recent research confirms that hops can adapt well to Italian conditions [13,14] and produce high-quality yields [15].



**Figure 1.** Number of hop-growing farms and utilised agricultural area in Italy (2020–2024) (source: own elaboration on AGEA data).

The brewing sector itself remains a fertile ground for growth. In 2024, Italian beer production reached 17.2 million hectolitres, marking a 6% decrease compared to the peak recorded in 2022. This decline is in line with pre-pandemic levels [16]. Furthermore, in 2024, Italian beer consumption reached 21.5 million hectolitres, equivalent to 36 litres per capita [17]. Despite the sustained growth in the sector, per capita consumption in Italy remains well below the EU average of 69 litres, suggesting considerable scope for future expansion in demand.

To the best of available knowledge, no existing study has systematically examined the economic performance of these farms at a micro-level. This study aims to fill that void by analysing a sample of 14 hop-producing farms observed between 2021 and 2023. This study is conceived as an exploratory, hypothesis-generating analysis aimed at identifying emerging economic patterns and farm typologies in a still-developing sector. While the sample is small, it covers nearly one-fifth of Italy's total hop-growing area, providing a solid foundation for exploratory analysis. The central research question is whether identifiable economic strategies or recurring farm profiles exist that can guide future policy and development. To address this, a two-stage multivariate approach was employed, combining Principal Component Analysis (PCA) with fuzzy clustering to define soft typologies in this evolving landscape. The rationale for combining PCA and fuzzy clustering has been clarified in the methodological section, where the two techniques are presented as complementary tools within an exploratory framework. Qualitative evidence was also incorporated to provide context on the technical and regulatory constraints facing the supply chain, thereby enhancing the analytical robustness and supporting a more contextually grounded interpretation of the quantitative findings. The paper is organised as follows. Section 2 describes the research methodology adopted; Section 3 details the structural and economic results; Section 4 discusses these findings; and Section 5 concludes with policy implications and future research directions.

## 2. Materials and Methods

### 2.1. Research Design

This study adopted an exploratory quantitative research design aimed at identifying structural and economic patterns among hop-producing farms in Italy. Due to the sector's emerging status and limited data availability, the analysis targeted farm-level economic performance using harmonised Italian FADN microdata. Through the application of PCA and fuzzy clustering to a set of synthetic indicators, the study characterises the economic profile of hop farms and identifies recurring patterns to delineate farm typologies.

To improve the interpretation of the quantitative results, the analysis is supplemented with contextual qualitative evidence drawn from primary and secondary sources. Rather than being treated as a formal qualitative dataset, this material serves exclusively to contextualise farm strategies, supply chain relationships, and structural constraints. In practice, it relies on two main elements:

- A detailed case study of a specialised hop-producing farm, which provides primary qualitative evidence supported by the farm's accounting data;
- Contextual insights emerging from discussions held during a scientific conference on the Italian hop supply chain.

These elements inform the quantitative findings, although they do not constitute a structured qualitative dataset. The overall framework of the study is therefore primarily quantitative and based on FADN microdata, while qualitative elements are incorporated only at the interpretative stage. These elements do not constitute a formal mixed-methods design and do not affect the construction of the farm typologies but only support the contextual interpretation of the statistical results.

### 2.2. Data Source

The data used in this study are drawn from the Farm Accountancy Data Network (FADN), the main harmonised system for collecting structural and economic information on commercial farms at the EU level. Established in 1965 to monitor farm income and structural dynamics and to support the evaluation of the Common Agricultural Policy (CAP), FADN provides detailed and standardised microdata on land use, labour, production, revenues,

subsidies, and costs. It has been extensively employed in empirical research to analyse farm performance, efficiency, and structural change across different agricultural sectors and countries [18–20].

The original sample consisted of all hop-producing farms identifiable within the Italian FADN database over 2021–2023, corresponding to 14 farms and 36 farm-year observations. Farms were included on the basis of the recorded presence of hop cultivation in their production structure during the reference period. After the outlier detection (see Section 2.4), four observations were excluded. The final dataset, consisting of 32 farm-year observations from 13 farms, was used for descriptive statistics, PCA, and fuzzy clustering.

A specialised hop farm was additionally investigated as a qualitative case study. Its accounting records for 2021–2023 were reconstructed using FADN definitions in order to ensure comparability. The farm was projected onto the PCA space for interpretative purposes, but it was not included in the clustering procedure.

Given the limited number of hop-producing farms available within the Italian FADN over the period considered, the dataset should be interpreted as a small but information-rich subset of the emerging national sector. Accordingly, the analysis is exploratory in nature and does not aim at statistical inference or population-level representativeness.

### 2.3. Analytical Approach and Methodological Framework

This study adopts a multidimensional analytical framework based on a set of synthetic farm-level indicators calculated over a three-year period. This framework is designed to capture both average economic performance and its interannual variability. To ensure comparability across farms, all indicators were expressed per hectare of utilised agricultural area (UAA) under hop cultivation.

Gross margin (GM) is defined as the difference between total output and variable costs per hectare of UAA and represents a standard indicator of gross profitability within the Italian FADN accounting methodology. In practice, it offers a direct measure of the farm's capacity to cover variable costs.

Income stability was assessed using the coefficient of variation in GM ( $GM_{cv}$ ), which is calculated by dividing the standard deviation by the mean GM over the observation period. This dimensionless indicator captures income volatility driven by variations in yields, input costs, or prices. For the two farms with a single observation, the median  $GM_{cv}$  of the remaining sample was imputed to preserve sample completeness. Robustness checks were conducted by excluding  $GM_{cv}$  to assess the sensitivity of the results (Section 3). As some farms exhibited negative or near-zero mean GM,  $GM_{cv}$  was treated as an exploratory indicator. A sign convention was adopted where negative values denote a negative mean GM, while absolute values reflect variability. This approach maintains comparability while ensuring the interpretation of segmentation results remains unaffected.

Variable costs (VCs) represent annual expenditure on production-related inputs and services, including seedlings, fertilisers, plant protection products, irrigation, energy, non-permanent labour, and contracted services, in accordance with the FADN methodology. VC expressed per hectare of hops within UAA was considered as a proxy for operational scale and input intensity. In combination with output, they contributed to the assessment of efficiency differences across farms. It should be noted that gross margin and variable costs are not fully independent, since variable costs enter directly into the calculation of gross margin. They were nevertheless retained as separate variables because they capture two distinct aspects of farm performance, namely cost intensity and net economic return.

Production scale was measured through the quantity of hops produced ( $Q_{HOP}$ ), expressed in physical units per hectare. Differences in  $Q_{HOP}$  help distinguish farms operating at commercial scale from those still in experimental or early development stages. A

joint analysis of Q\_HOP and VC provides preliminary insights into input-output efficiency and technology adoption. However, a limitation of this indicator is that it does not distinguish between fresh and dried hops, which differ substantially in terms of yields, costs, and prices. Given the lack of information on product form in the dataset, comparability of productivity and efficiency indicators across farms may be affected, and the results should therefore be interpreted as indicative of relative performance patterns rather than precise efficiency benchmarks.

Production orientation was analysed through the specialisation ratio (SH), calculated as the share of total gross output attributable to hops. The ratio ranges between 0 and 1: values close to zero indicate marginal revenue from hops, whereas values approaching one reflect full specialisation. SH therefore helps characterise farm strategies and differentiate specialised from diversified profiles in the typology analysis.

To further clarify the conceptual framework, Table 1 summarises the economic interpretation of the indicators used in the analysis and their link to key dimensions of farm performance.

**Table 1.** Economic interpretation of the indicators used in the analysis.

Variable	ID	Economic Dimension	Interpretation
Gross Margin [€/ha]	GM	Profitability	Measures the farm's ability to generate returns from hop cultivation after covering variable costs
Variable Costs [€/ha]	VC	Cost structure/ Input intensity	Captures the level of input use and operational intensity associated with hop production
Hop Output [quintals/ha]	Q_HOP	Production scale/Productivity	Reflects productive capacity and distinguishes commercial from small-scale or experimental production
Specialisation Ratio	SH	Strategic orientation	Indicates the implementation level of hops within the farm's overall production strategy
Coefficient of Variation in GM	GM_cv	Income stability/Risk	Captures the variability and stability of economic performance over time

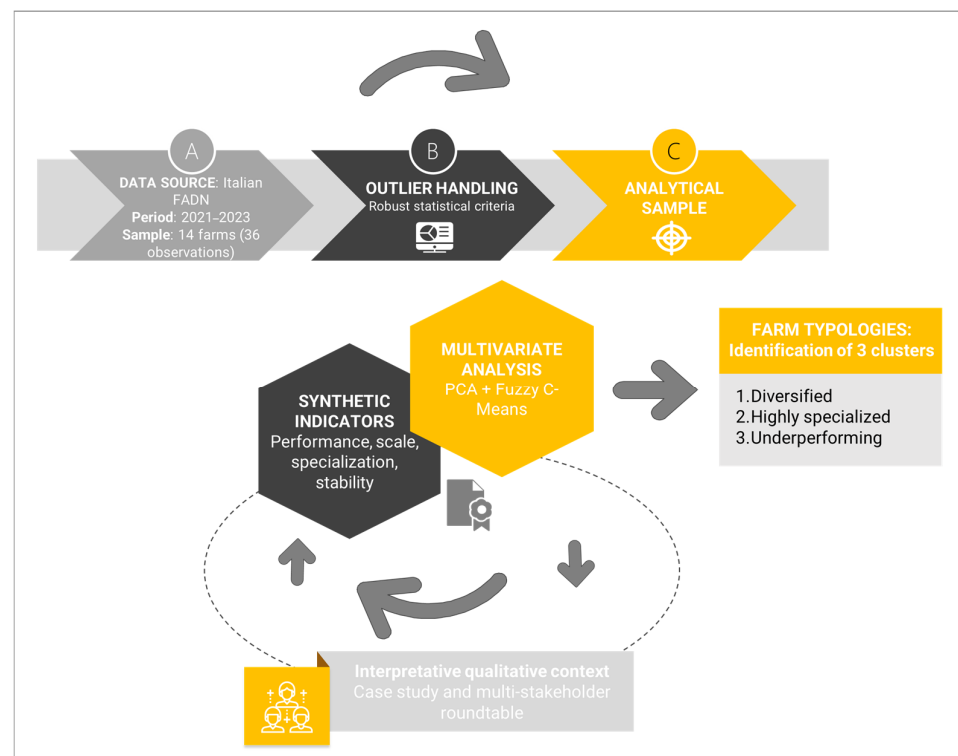
The analytical framework is built around three interrelated dimensions of farm performance: production orientation (specialisation), technical performance (as reflected in output and input use), and income stability (captured through interannual variability). These dimensions are not independent, as higher levels of specialisation may be associated with both improved technical performance and greater exposure to income variability. Taken together, they provide a coherent basis for interpreting the economic profiles of the farms.

Based on the indicators and analytical dimensions described above, Figure 2 provides a schematic overview of the analytical process adopted in this study, illustrating the sequence of data preparation, indicator construction, outlier detection, and multivariate analysis.

#### 2.4. Multivariate Statistical Analysis

Given the exploratory nature of this study, particular attention was paid to data quality prior to multivariate analyses. A robust outlier procedure was therefore implemented, combining two complementary methods: the Interquartile Range (IQR) criterion based on Tukey's rule [21], and a skewness-adjustment approach integrating Medcouple-adjusted boxplots with Modified Z-Scores [22–24]. The IQR method identifies extreme values outside

1.5 times the interquartile range. The Medcouple-adjusted approach, in contrast, accounts explicitly for distributional asymmetry and is therefore better suited to economic variables such as gross margins.



**Figure 2.** Methodological approach adopted.

When applied to the raw dataset, the Medcouple procedure identified three observations from the same farm with exceptionally high gross margins, indicating atypical economic conditions. The Modified Z-Score analysis based on the median absolute deviation (MAD) detected one additional anomalous observation from another farm. In total, four observations were excluded, leaving 32 farm-year observations from 13 farms. The excluded observations were individually examined to ensure that their removal did not affect the internal coherence of the dataset. Removing these values improved the robustness of the multivariate analyses by limiting the influence of extreme values. The resulting dataset was used as the input for the PCA and fuzzy clustering described in the following sections.

Prior to multivariate analysis, all continuous variables were standardised using Z-scores. This accounted for differences in measurement units and ensured that each variable contributed equally to the clustering process.

PCA was then applied to the correlation matrix of the standardised variables to reduce dimensionality, address multicollinearity, and summarise the main dimensions of variation in the data, providing a simplified representation for subsequent clustering [25–28] in an exploratory analysis based on a small sample.

Farm typologies were identified using fuzzy C-means clustering [29–33], which assigns degrees of membership to each cluster rather than hard classifications. This combined approach is particularly suited to small samples and contexts characterised by overlapping strategies, as PCA summarises the main dimensions of variation, while fuzzy clustering allows the identification of recurring farm configurations without relying on statistical inference. The algorithm minimises an objective function that combines the weighted distance of each observation from the cluster centroids with a fuzziness parameter  $m$ , which was set to the commonly used value of 2. Several values for the number of clusters

( $C = 2, 3, 4$ ) were tested. The solution with  $C = 3$  was selected based on the partition coefficient, partition entropy, and the interpretability and balance of the resulting groups.

The resulting membership matrix ( $N \times 3$ ) allows each farm to be associated with the cluster exhibiting the highest membership value while retaining information on partial affiliations. Cluster centroids were expressed in standardised form and subsequently back-transformed to the original variable scale using inverse Z-score transformation, enabling meaningful comparisons of average values per hectare for GM, VC, Q\_HOP, specialisation, and GM\_cv across clusters.

All statistical analyses were conducted using the R statistical environment (version 4.4.0; R Core Team, 2024, R Foundation for Statistical Computing, Vienna, Austria), with PCA and fuzzy clustering implemented through dedicated multivariate packages.

### 2.5. Qualitative Contextual Evidence: Data Sources and Analytical Approach

In line with recent contributions that adopt case-based qualitative evidence as interpretative support, rather than as a formal explanatory design, this study uses qualitative insights to contextualise the quantitative results [34]. This choice responds to the need to go beyond simply identifying statistical associations and offer a deeper understanding of how and why these relationships manifest in a given empirical context. Integrating the qualitative component reinforces the substantive interpretation of the observed coefficients and trends. Moreover, this interpretative use of qualitative material is consistent with methodological contributions emphasising iterative pattern matching between theoretical expectations and empirical observations, even in exploratory and single-case designs, as a means of enhancing contextual understanding without compromising quantitative rigour [35]. In this study, qualitative evidence is used to refine and, where necessary, reconsider the initial theoretical framework. This is relevant when analysing socio-economic dynamics that are shaped by heterogeneous conditions. The qualitative component complements the statistical analysis by supporting the interpretation of the results and clarifying the scope of the proposed explanations.

A dual interpretative approach aimed at contextualising the quantitative results was adopted.

An in-depth case-based analysis was conducted on a highly specialised hop-producing farm identified as a structurally coherent and economically successful configuration emerging from the quantitative typology. To ensure confidentiality, all information allowing farm identification has been omitted. Data for the case study were derived from farm accounting records reconstructed for the 2021–2023 period using the same definitions and procedures adopted in the Italian FADN and from a semi-structured interview with the manager of the selected case-study farm. This interview was conducted for illustrative and interpretative purposes only and was not intended to provide a representative qualitative sample. It focused on the farm's development trajectory, motivations for entering hop production, technical and organisational choices, marketing strategies, and perceived constraints and opportunities. The material was coded into four dimensions: (i) entry motivations, (ii) production strategy and technical management, (iii) marketing channels and relationships with buyers, and (iv) risk management and future plans.

Additional qualitative input emerged from a national institutional discussion panel involving hop growers, supply chain stakeholders, and craft beer producers. This material was not collected through individual interviews and was not treated as a formal qualitative sample. Instead, it was used exclusively as contextual evidence to support the interpretation of the quantitative results at the sector level. The discussion provided a broader sectoral perspective on production strategies, supply chain organisation, market relations, and institutional constraints affecting hop cultivation in Italy. The qualitative

material was analysed using a thematic content approach, consistent with exploratory and interpretative approaches commonly adopted in agri-food and rural studies [36,37], triangulating evidence from the case-study farm, expert contributions from the conference, and detailed farm accounting data from the quantitative analysis. The objective was to identify recurring patterns that help explain the economic performance observed in the quantitative phase and to describe the structural and managerial conditions associated with the specialised hop-farm profile. In the Section 3, the case study is presented alongside the quantitative typology to highlight convergences and specific features, improving the interpretation of the cluster representing highly specialised and efficient hop producers.

Given the limited number of interviews and the complementary role of the conference-based material, the qualitative evidence is not framed within a formal mixed-methods design. Instead, it is used to support the interpretation of quantitative typologies and to illustrate the conditions under which hop cultivation may become an economically viable component of farm development strategies. The qualitative findings are interpretative rather than representative and do not imply formal generalisation. For this reason, references to qualitative evidence should be interpreted as illustrative and contextual rather than as the outcome of a structured interview-based analysis.

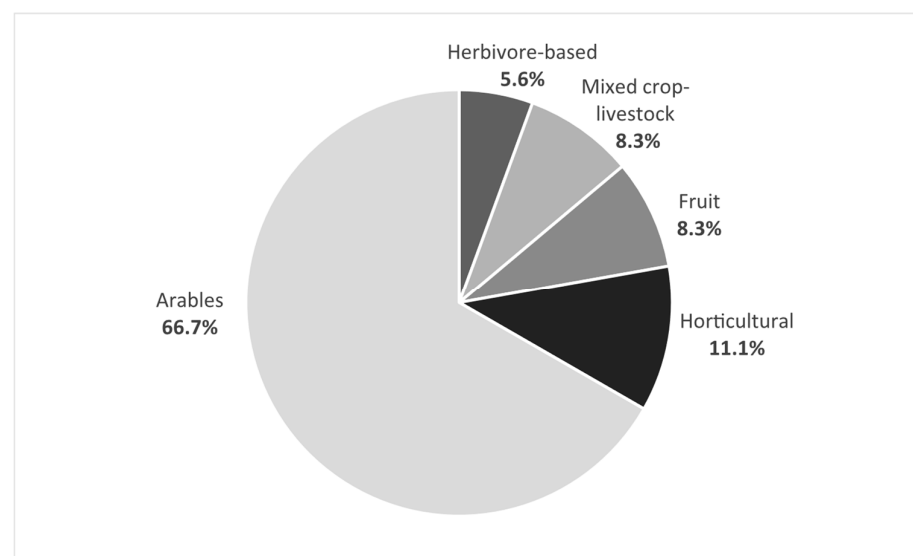
The combined use of FADN data and qualitative evidence supports structural and economic profiling in a small but information-rich sector, providing a more detailed understanding of farm-level behaviour. This contributes to the interpretative and practical relevance of the proposed typology [38].

### 3. Results

#### 3.1. Structural and Economic Profile of the Sampled Farms

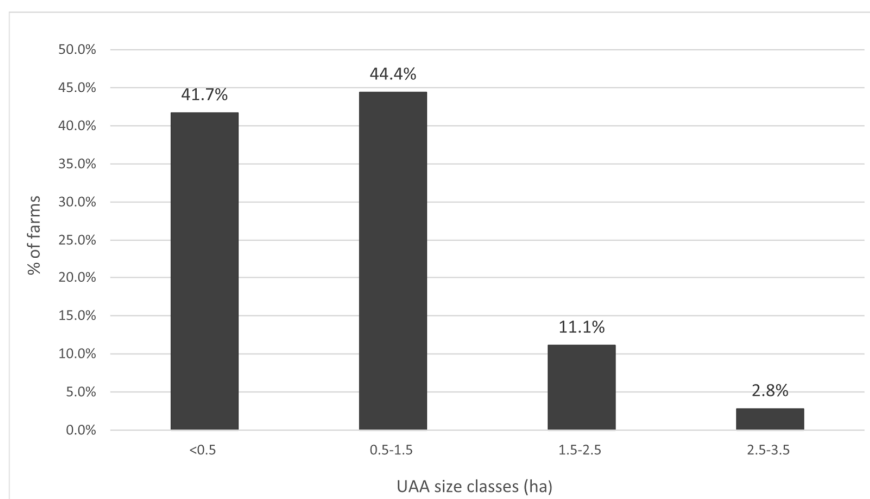
The structural and economic profile derived from the validated dataset captures key features for an initial characterisation of the Italian hop sector.

According to the EU farm typology, most holdings are classified as arable farms (66.7%), followed by horticultural (11.1%), fruit (8.3%), mixed crop-livestock (8.3%), and herbivore-based (5.6%). As illustrated in Figure 3, hop cultivation is typically integrated into broader crop-based systems rather than serving as the primary farm activity.



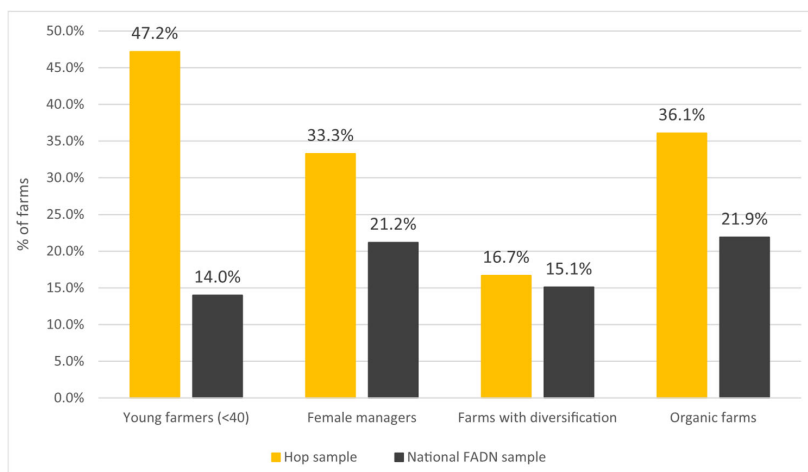
**Figure 3.** Distribution of the sampled farms by EU typology (source: own elaboration based on FADN data).

Regarding economic size, 47.2% of the sample falls into the medium class (€25,000–100,000 Standard Output), while 30.6% and 22.2% belong to the large (>€100,000) and small (€8000–25,000) classes, respectively. The average UAA per farm is 19.1 ha, significantly lower than the national FADN average of 39.9 ha. This pattern points to a role for hop cultivation in farm diversification, particularly among smaller holdings. The average area allocated to hops is 0.85 hectares, which constitutes 6.6% of the UAA. Production is therefore concentrated in small-scale plots, with 86.1% of farms managing less than 1.5 ha (Figure 4).



**Figure 4.** Distribution of hop-growing farms by UAA size class (source: own elaboration based on FADN data).

The demographic profile reveals significant deviations from national FADN benchmarks (Figure 5). Farmers under the age of 40 account for 47.2% of the sample, which is significantly higher than the national average of 14.0%. This appeal among the young is likely to stem from the crop’s potential for innovation and integration into craft brewing supply chains, thereby highlighting a role for hops in generational renewal. Women manage 33.3% of the sampled farms, which exceeds the national average of 21.2%. While diversification levels (16.7%) align with national figures (15.1%), organic certification is significantly more prevalent (36.1% vs. 21.9% nationally), indicating a robust environmental orientation and closer alignment with local market demands.

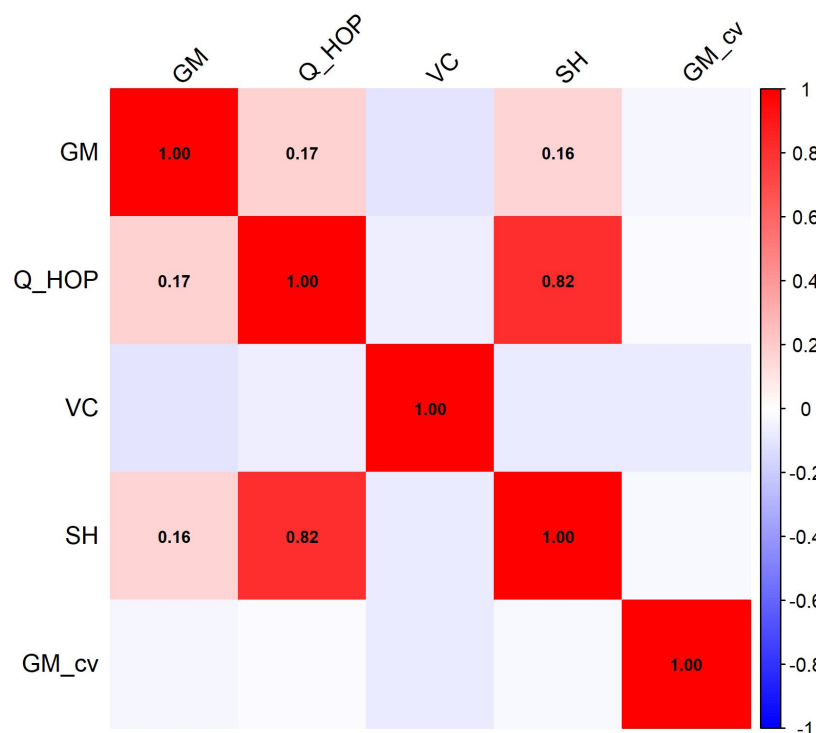


**Figure 5.** Comparison between the hop farm sample and the national FADN sample across key demographic and structural variables (source: own elaboration based on FADN data).

Despite the limited physical area occupied, hop cultivation remains economically significant, accounting for an average of 23.2% of total gross output. This confirms that the crop, while not land-dominant, represents a cornerstone of the income strategy for these holdings.

### 3.2. Results of the Quantitative Analysis: PCA and Fuzzy Clustering

PCA was applied to the standardised data to explore the underlying structure of the dataset. Regarding the five principal components generated, the first two captured approximately 60% of the total variance (PC1 approximately 38%, PC2 approximately 22%), which is consistent with the limited number of variables and the exploratory nature of the analysis. In this context, the objective of the PCA is not to maximise explained variance but to identify the main structural gradients underlying farm heterogeneity. A slightly higher proportion of explained variance was observed when GM\_cv was excluded from the analysis. The correlation matrix (Figure 6) shows generally weak pairwise associations, with the exception of a strong positive relationship between Q\_HOP and SH. No critical multicollinearity was detected among the variables, although gross margin and variable costs are mechanically related, since the latter is a component of the former. The first component (PC1) had strong positive loadings on GM and Q\_HOP and negative loadings on GM\_cv and VC. PC1, therefore, reflects a gradient from high-performing, efficient farms to those with lower margins and greater volatility. Although GM and Q\_HOP are only weakly correlated ( $r = 0.17$ ), they both independently contribute to the variance explained by PC1, reflecting patterns that are not evident in simple correlations. The second component (PC2), driven mainly by the specialisation ratio and GM\_cv, differentiates between more specialised and more diversified farms, as well as between stable and unstable income profiles. The two-dimensional representation facilitated the identification of clusters and the interpretation of farm profiles.



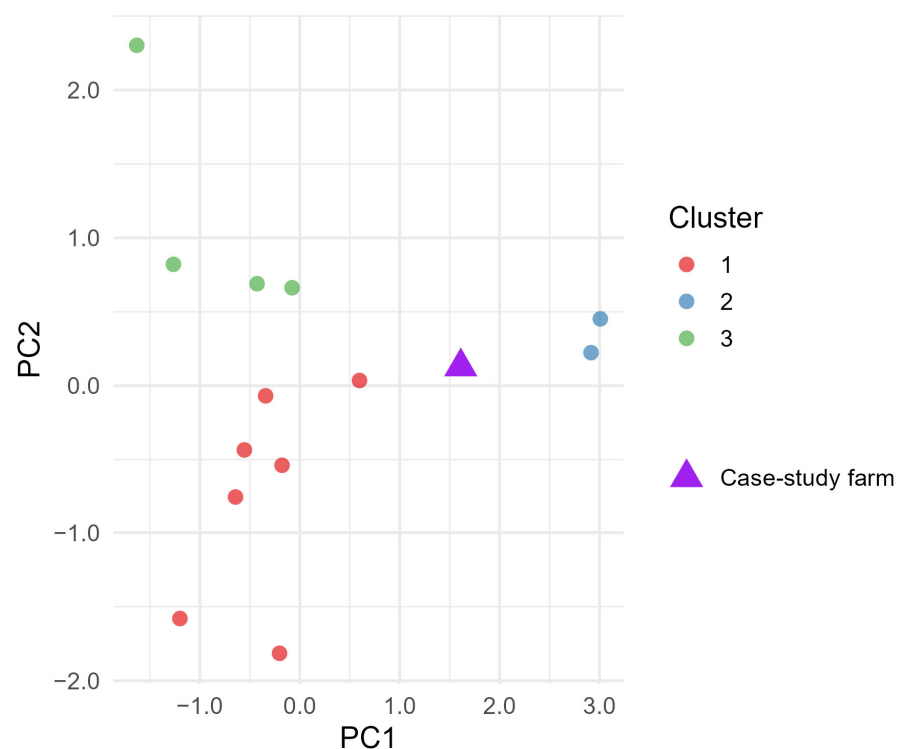
**Figure 6.** Pearson correlation matrix between the standardised variables used in the PCA (source: own elaboration based on FADN data). Abbreviations: GM = gross margin (€); Q\_HOP = hop output (quintals); VC = variable costs (€); SH = specialisation ratio; GM\_cv = coefficient of variation in gross margin.

The matrix shows generally weak associations, except for a strong positive correlation between hop output (Q\_HOP) and the specialisation ratio (SH,  $r = 0.82$ ). This suggests that farms with larger hop production tend to rely more heavily on this crop in terms of income.

The multivariate analysis segmented the observed farms into three distinct groups, each characterised by specific economic profiles and degrees of specialisation in hop production. Although the sample size is small, the fuzzy C-means algorithm produced well-defined cluster memberships, with most farms showing high affiliation scores ( $>0.8$ ) to their respective clusters. This reflects both the internal consistency of the clusters and the clear differences in structural and economic characteristics.

As previously mentioned, it should be noted that the dataset does not differentiate between fresh and dried hop yields. Given the substantial differences in yield, price, and production costs between the two forms (fresh and dried hops), this limitation should be considered when interpreting productivity and economic outcomes, particularly in relation to comparability across farms and efficiency-related assessments.

The clustering results are presented below, focusing on the distinctive features of each group. Figure 7 shows the position of the farms and the case study in the PCA plane.



**Figure 7.** Projection of hop farms in the PCA plane (PC1–PC2), based on five standardised variables (GM, VC, Q\_HOP, SH, GM\_cv) (source: own elaboration based on FADN data).

Each point is representative of a single farm and is coloured according to its cluster. The case-study farm is marked distinctly (purple triangle). The two components together explain 60% of total variance and reveal a clear segmentation by economic performance and specialisation.

#### Cluster 1—Diversified but economically solid farms

This group comprises seven diversified but economically robust farms. They have some of the highest average gross margins from hop cultivation (approximately €16,340), with moderate interannual variability (GM\_sd around €11,290). However, the average share of hops in total gross output remains low (SH about 0.1), which reflects a limited degree of specialisation. Hop output is modest (in the order of 15.6 quintals per hectare),

and variable costs are relatively low (approximately €3180), consistent with the presence of hops alongside other crops. The broader economic stability derived from more established production lines appears to support the maintenance of small-scale hop production and, in some cases, experimentation. In the absence of specific incentives or clear market signals, scaling up does not appear to be a strategic priority.

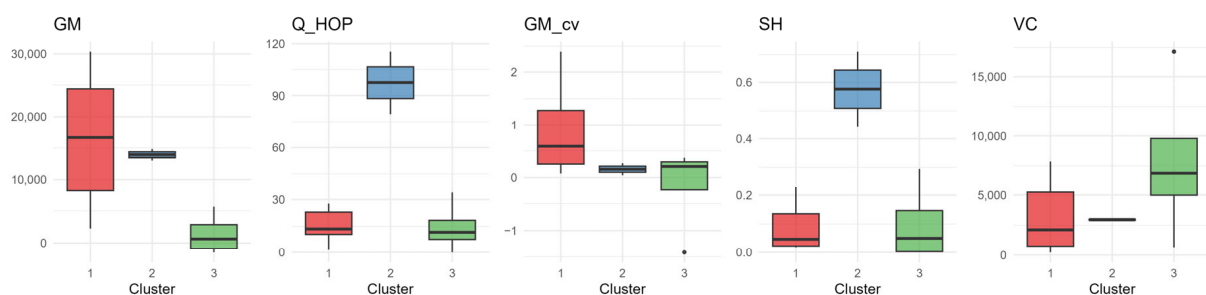
#### Cluster 2—Highly specialised and efficient hop producers

Cluster 2 includes two farms with a markedly different profile. They are characterised by high specialisation (SH approximately 0.6) and strong technical and economic performance. These farms report consistent margins from hops (GM about €13,918), with minimal interannual variability (GM\_sd around €1257). They achieve the highest average hop production (about 97.5 quintals per hectare) while keeping moderate and stable variable costs (approximately €2964). The combination of high specialisation and technical efficiency characterises a production configuration in which hop cultivation appears economically sustainable at the observed scale. This configuration may serve as a reference point for new entrants and for the gradual consolidation of the sector.

#### Cluster 3—Underperforming and fragile farms

This group includes the four farms with the weakest performance. They record the lowest average gross margins (approximately €1367) and the highest income variability (GM\_sd about €3222), which suggests unstable returns. Despite their low level of specialisation (SH around 0.1), these farms have the highest average variable costs in the dataset (approximately €7898), while their output remains modest (in the order of 14.3 quintals per hectare). This combination suggests limited scale and technical inefficiency, which undermines economic viability. These results highlight the risks of engaging in hop cultivation without adequate scale, technical capacity, or secure market access. The marked internal heterogeneity within this group suggests that, while some farms may have potential for improvement, others are likely to remain structurally unsustainable.

Overall, the segmentation reveals three distinct profiles, which are defined by their specific levels of specialisation, economic performance, and income stability. This is illustrated by the distribution of key variables across the clusters in Figure 8, while average cluster values are reported in Table 2.



**Figure 8.** Distribution of key variables by cluster (source: own elaboration based on FADN data). Abbreviations: GM = gross margin (€); Q\_HOP = hop output (quintals); VC = variable costs (€); SH = specialisation ratio; GM\_cv = coefficient of variation in gross margin. Black dots represent outliers.

Boxplots showing the variability of the main structural and economic indicators across the three farm clusters identified through fuzzy clustering analysis.

Detailed cluster assignment and membership values for individual farms are reported in Table 3.

**Table 2.** Mean values of selected economic and structural indicators by cluster (source: own elaboration based on FADN data).

Cluster	GM	Q_HOP	VCs
1	16,341.7	15.6	3178.5
2	13,918	97.5	2963.6
3	1366.9	14.3	7897.8

Abbreviations: GM = gross margin (€); Q\_HOP = hop output (quintals); VCs = variable costs (€).

Reported values represent the average gross margin, hop yield, variable costs, specialisation ratio, and coefficient of variation in gross margin for each cluster. However, as noted in the methodology, these results should be interpreted with caution, as the dataset does not distinguish between fresh and dried hops, and the output indicator (Q\_HOP) is affected by this limitation. This should be taken into account in the interpretation of the results.

**Table 3.** Cluster assignment and structural indicators of the analysed farms (source: own elaboration based on FADN data).

Farm Code	GM	Q_HOP	VC	SH	GM_cv	Obs	Cluster	M1	M2	M3
Farm_01	−672.7	0.0	672.7	0.0	−1.4	2	3	0.07	0.01	0.92
Farm_02	19,152.7	9.6	2130.1	0.0	0.1	3	1	0.93	0.01	0.06
Farm_03	2282.6	1.4	427.5	0.0	1.7	3	1	0.81	0.05	0.15
Farm_04	13,322.2	11.1	233.3	0.0	0.3	3	1	0.99	0.00	0.01
Farm_05	3021.2	26.1	1101.2	0.2	2.4	3	1	0.81	0.07	0.12
Farm_06	5663.7	13.1	6429.8	0.3	0.1	3	3	0.20	0.05	0.76
Farm_07	30,361.1	27.7	7868.3	0.2	0.6	3	1	0.50	0.17	0.33
Farm_08	16,633.4	19.6	6976.6	0.1	0.8	3	1	0.68	0.03	0.29
Farm_09	1966.5	34.0	7328.5	0.1	0.4	2	3	0.08	0.02	0.90
Farm_10	−1490.0	10.0	17,160.0	0.0	0.3	1	3	0.18	0.08	0.74
Farm_11	13,029.2	79.4	2961.7	0.7	0.0	3	2	0.00	1.00	0.00
Farm_12	14,806.9	115.5	2965.5	0.4	0.3	1	2	0.00	1.00	0.00
Farm_13	29,618.8	13.4	3512.5	0.0	0.2	2	1	0.94	0.01	0.05

Abbreviations: GM = gross margin (€); Q\_HOP = hop output (quintals); VC = variable costs (€); SH = specialisation ratio; GM\_cv = coefficient of variation in gross margin.

Descriptive statistics for the 13 farms included in the analysis, including gross margin, hop output, variable costs, specialisation ratio, coefficient of variation in gross margin, number of observations, cluster assignment, and fuzzy membership degrees resulting from the clustering analysis.

Although it was not included in the clustering procedure, the case-study farm was projected onto the PCA space for comparative purposes. Its profile, characterised by high specialisation, stable yields, and positive gross margins, aligns closely with the most consistent and high-performing farms in the sample.

A sensitivity test was conducted by excluding GM\_cv from the PCA and clustering analysis. This choice was driven by the presence of two farms with only one observation each, preventing direct calculation of interannual variability. In the main analysis, GM\_cv for these farms was imputed using the sample median to preserve completeness, although this procedure may not fully reflect actual income volatility. Excluding GM\_cv led to a higher proportion of variance explained by the first two principal components (73.4% compared to 59.5%), corresponding to a more compact statistical structure. However, the resulting cluster structure remained largely unchanged, with only one farm shifting from Cluster 2 to Cluster 1. The segmentation therefore appears to be driven mainly by structural and economic variables, while GM\_cv contributes by capturing income stability. Although

this approach may introduce some bias, its impact appears limited, as the exclusion of GM\_cv did not substantially alter the cluster structure.

In both versions of the analysis, the case-study farm consistently aligned with Cluster 2, confirming its position among the specialised and high-performing hop farms.

### 3.3. Qualitative Analysis Results

This section outlines the qualitative findings from a specialised hop farm in Emilia-Romagna. Evidence was gathered through anonymised, reconstructed FADN accounting records, semi-structured interviews with the entrepreneurs, and insights from a technical panel on the Italian hop supply chain.

#### 3.3.1. Case Study Profile and Trajectory

The case-study farm is a family-run arable farm managed by two young entrepreneurs. Hop cultivation was introduced in 2016 as a secondary farm activity but has gradually become the farm's main specialisation. To date, the farm cultivates approximately 5.5 hectares of hop fields, with a clear expansion strategy for the coming years. Production consists mainly of American hop varieties, with a particular focus on varietal adaptation to the soil and climate conditions of the Italian growing area.

The agronomic management follows an organic approach, made necessary in large part by the current institutional framework. In Italy, there are currently no plant protection products registered specifically for hop cultivation, even within organic systems, forcing growers to rely on sustainable practices, mechanical control, and foliar fertilisation.

From a structural point of view, the farm examined has a high level of capitalisation and also benefits from full ownership of the factors of production. This allowed it to sustain the significant initial investments associated with hop cultivation while also ensuring financial stability.

In relation to the qualitative evidence that emerged from the interview, the decision to specialise in hop cultivation derives from the structural dependence of the Italian beer sector on the importation of raw ingredients, given that until a few years ago, the hops used by Italian breweries were entirely imported. The rapid expansion of the domestic craft beer market in recent years has generated considerable interest in this product, identifying it as a high-potential niche product, characterised by strong growth in demand and limited internal offerings.

From the outset, the farm framed hop cultivation not as a marginal diversification activity, but rather as a long-term entrepreneurial investment project aimed at positioning the business within an emerging agri-food supply chain. This strategic orientation explains the entrepreneurs' willingness to undertake high sunk investments during the early years of establishment, despite the technical and market uncertainties that characterised the sector at that time.

A serious critical issue that the company must address concerns the post-harvest phase. Specifically, after harvesting, fresh hops must be immediately dried and pelletised to prevent deterioration. This requires adequate workforce availability close to the hop maturation time, processing capacity, and technical expertise. At the same time, the lack of specific hop harvesting machinery produced in Italy forced local farms to import it, causing high investment costs. Overall, both harvesting and post-harvest operations represent major cost drivers, with investment decisions closely linked to expected sales volumes rather than to production capacity alone.

#### 3.3.2. Structural and Economic Performance

Reconstructed FADN data revealed exceptional performance. Total revenues reached €124,491, with Gross Saleable Production (GSP) at €109,491. Operating income exceeded

70% of revenues, aided by contained operating costs and an absence of wage labour or debt. Land productivity was particularly high: gross productivity (PLV/SAU) reached €19,907 per hectare, while net productivity (VA/SAU) exceeded €16,000 per hectare. A high mechanisation level (26 kW per hectare) reflected a capital-intensive, labour-saving model consistent with high-performing profiles.

### 3.3.3. Business Model and Supply Chain Integration

A defining feature of the case-study farm is its strong vertical and relational integration within the hop-beer supply chain. The farm operates in close coordination with a specialised intermediary organisation that bridges the gap between hop producers and craft breweries, managing post-harvest operations, quality control, and market access. This intermediary performs several key functions, including the organisation of drying and pelletisation, quality certification via blind sensory panel tests, and translation of the agronomic attributes of Italian hops into technical, brewing-relevant information for beer producers.

Qualitative data show that there are significant information asymmetries in the hop supply chain; in fact, in the absence of intermediaries, the matching of supply and demand is not efficient. In a sector that remains strongly dependent on imports, a coordinated market configuration would facilitate the establishment of Italian hops on the national market. Currently, the supply system uses a mixed commercial strategy, whereby imported hops are used to maintain stable, long-term relationships with breweries, while Italian products are gradually (but slowly) being introduced to the market.

### 3.3.4. Sectoral Insights from Technical Panel

The qualitative evidence that emerged from the conference debate outlines an Italian hop sector characterised by significant fragmentation, with fragile institutional support. One limitation to the development of the supply chain is clearly the reluctance of national breweries to use hops grown in Italy. In fact, according to what was expressed during the panel discussion, this resistance on the part of breweries is related to the fact that hops grown in Italy tend to have organoleptic profiles that differ from the standardised sensory references of the variety at the international level. Furthermore, from a beer production point of view, the specific style of beer requires 'standard' organoleptic parameters from the hops, and, as a result, this type of product diversification is often interpreted by brewers as an inconsistency rather than a distinctive (potentially positive) attribute, limiting the acceptance of hops produced in Italy. The sector is still emergent and therefore lacks collective organisation, which limits its political leverage. Specifically, growers are still waiting for approved regulations on the registration of plant protection products that can be used. In the absence of such regulations, access to public support measures is limited, and commercial penetration is consequently weakened. Collective aggregation mechanisms between farmers and more coordinated governance structures are therefore essential to enable sector consolidation.

Given the issues that have emerged, Italian hop-producing farms tend to adopt adaptive development strategies aimed at reducing exposure to business risks in the sector. In fact, rather than implementing rapid expansion strategies, many producers prioritise incremental growth and product differentiation. Long-term strategic orientations are increasingly focused on consolidating relationships in the supply chain, improving product quality, and building a recognisable national positioning for Italian hops. This change reflects the structural conditions of the sector, where competitiveness is less determined by company size and more by coordination, reputation, and supply chain contracts. These factors are key mechanisms for improving economic profitability in a context of structural and institutional fragility.

The qualitative evidence also provides insight into the motivations underlying the adoption of hop cultivation. Farmers are primarily attracted by the growth potential of the craft beer sector and the opportunity to enter a high-value niche market. In addition, the potential for relatively high yields per hectare and the comparatively high market price per kilogram make hop cultivation an attractive option for farm diversification strategies. However, these decisions are generally made in the absence of guaranteed sales, particularly in the early stages of sector development. This market uncertainty represents a key constraint, and successful farms tend to mitigate this risk through the development of supply chain relationships, often involving intermediaries or direct agreements with breweries.

### *3.4. Integration of Qualitative and Quantitative Evidence*

The qualitative case study helps to contextualise the high-performing and highly specialised cluster identified in the quantitative analysis.

A key element strengthening the integration between qualitative and quantitative evidence lies in the comparability of the data. The structural and economic indicators of the case-study farm were reconstructed using the same FADN definitions and accounting criteria applied to the sample, ensuring full methodological consistency. This allows for a direct comparison between the case-study farm and the clusters identified in the quantitative analysis. The strong alignment between the case-study indicators and the profile of Cluster 2 supports a clear association between the two, reinforcing the internal coherence of the typology. Building on this alignment, the qualitative evidence derived from the interview provides insight into the underlying mechanisms driving this performance. In particular, factors such as high specialisation, investment in post-harvest processes, and strong supply chain integration help explain the stable margins and efficiency patterns observed in the quantitative results.

Specifically, the farm exhibits the same structural and economic configuration observed among the most efficient hop producers: high capitalisation, strong specialisation, stable margins, controlled variable costs, and financial autonomy.

However, the qualitative evidence also shows that economic performance cannot be explained by scale alone, but rather by a coherent strategic alignment between entrepreneurial orientation, technical organisation, post-harvest integration, and supply chain coordination. Therefore, the case study clarifies why only a very limited number of farms in the sample achieve comparable levels of performance and income stability.

## **4. Discussion**

This study provides new empirical evidence regarding the structural and economic characteristics of Italian hop-producing farms, which are in an early stage of development and have not been extensively explored in the existing literature. By combining exploratory quantitative analysis with contextual qualitative evidence, the study identifies recurring profiles among the farms examined, providing more in-depth knowledge of the strategic, organisational, and relational mechanisms underlying the performance of this emerging sector.

The internal consistency of the identified clusters and their consistency with the observed agricultural strategies support the application of multivariate techniques in small and structurally heterogeneous samples. However, these clusters should not be interpreted as fully exhaustive representations of farm behaviour, as they are derived from a limited set of economic indicators and do not capture all agronomic, organisational, and market-related factors. At the same time, these limitations do not preclude the use of multivariate approaches for exploratory purposes in data-constrained contexts. In fact, despite the methodological constraints typically associated with small sample sizes, a growing number

of studies show that multivariate statistical techniques, such as PCA and clustering, can be effectively applied in structurally heterogeneous agricultural contexts with limited data availability. For example, hierarchical clustering has been used to identify typologies of agroecological transition among 40 Portuguese family farms [39], while fuzzy clustering has been applied to a sample of 15 small-scale agri-food producers in Mexico, demonstrating its suitability for capturing overlapping strategies in highly fragmented systems [40]. Similarly, multidimensional scaling and hierarchical clustering have supported the organisation of local producer groups among 40 Romanian organic farms [41]. Multivariate approaches have also been employed to analyse farmers' preferences and decision-making in segmented samples, such as broiler and pig producers in the Netherlands [42]. Moreover, simulation-based evidence indicates that PCA can yield interpretable results even with a limited number of observations, provided that the variables capture clearly distinct dimensions [43].

Within this methodological framework, the empirical analysis builds on FADN microdata, which have long been used in the Italian context to investigate farm structural dynamics, economic performance, and policy impacts, providing a consistent benchmark for interpreting farm-level heterogeneity in emerging and niche agricultural sectors.

To date, existing scientific research on hop cultivation in emerging producing countries has focused primarily on technical aspects such as agronomic adaptation and cultivar yields, while economic analyses of farm performance, organisational strategies, and income dynamics remain limited [5]. This bias in the literature highlights the importance of empirical economic analyses to support both farm-level decision-making and policy design in emerging hop production systems. Overall, the results show that farm performance in this emerging sector depends less on individual factors than on how well production choices, organisational structure, and market positioning align. Both specialisation and diversification can be viable strategies, but their effectiveness depends on the supporting technical capacity, post-harvest organisation, and commercial relationships.

Focusing on the Italian case, the study's results reveal that the hop sector in Italy is not homogeneous but comprises business models that differ in terms of specialisation, technical capacity, and economic stability. Within this diversity, Cluster 2, consisting of specialised and technically structured farms, is characterised by farms with stable margins and efficient use of production factors. In this context, the case study analysed helps to better understand the characteristics of this high-performance cluster. Specifically, this farm has a structural and economic profile comparable to that of the most efficient hop producers, including high capitalisation, strong specialisation, stable margins, controlled variable costs, and financial autonomy. However, qualitative evidence also suggests that economic performance is not only driven by scale but reflects a coherent strategic alignment between entrepreneurial orientation, technical organisation, post-harvest integration, and supply chain coordination. This helps to explain why only a very small subset of farms in the sample achieves similar levels of performance and income stability. This also suggests that such performance depends on a specific combination of structural and organisational conditions, which may be difficult to replicate in contexts where these conditions are only partially met. The alignment of the case study with Cluster 2 corroborates the interpretation of a feasible production model grounded in observed practice, suggesting that hop specialisation can represent a solid strategic pathway when supported by appropriate conditions. This is consistent with previous studies showing that success in niche sectors depends less on the specific crop type and more on consistent and coherent management strategies and structural choices. As highlighted by Cuthbert [44], strategic planning plays a pivotal role in strengthening competitiveness in niche markets. Similarly, von Münchhausen et al. [45] argue that business logic (the fit between goals, governance, and operational

practices) is a key driver of long-term sustainability. While Raveloaritiana and Wanger [46] demonstrate that diversification strategies generally enhance profitability, the findings suggest that in this specific high-input context, specialised coherence is equally critical. Clearly, the lack of differences between fresh and dried hops has significant implications for the interpretation of efficiency models, since the observed differences in productivity may be influenced by post-harvest processing decisions rather than solely by agronomic or management outcomes.

The interpretation of these quantitative results is further enriched by contextual insights emerging from a multi-stakeholder roundtable discussion with sector operators. These insights help clarify how supply chain structural conditions shape the varied strategies of the identified farm profiles.

The major fragilities observed in Cluster 3, which is less structured and characterised by unstable yields and fragile margins, are consistent with the technical difficulties that were highlighted during the roundtable. The critical absence of plant protection products specifically registered for hops increases agronomic uncertainty, while the lack of accessible, small-scale post-harvest facilities (drying, stabilisation, and pelletisation) creates a significant processing bottleneck affecting product quality and margins for these producers. These elements indicate that the weaknesses observed in this cluster are not simply temporary but reflect underlying structural constraints that limit the scope for improvement through incremental adjustments.

By contrast, the conservative strategy adopted by the more diversified farms in Cluster 1 significantly reflects barriers on the demand side. Insights from the discussion panel show a general reluctance among craft beer producers to take risks related to product innovation, preferring the standardised aroma profiles of imported hops over national hops with new aroma profiles. This is because the cultural barrier does not identify these differences as a higher quality linked to the domestic terroir but rather as a qualitative inconsistency in the hops. In this context, the emergence of specialised and high-performing hop farms reflects the capacity to generate value through product differentiation, territorial identity, and integration within the craft beer supply chain. In this sense, craft-based agri-food systems represent hybrid economic domains in which agricultural production is closely intertwined with cultural and creative dynamics. Recent contributions [47,48] highlight how the craft sector contributes to regional development, innovation, and sustainable value creation within the broader context of the creative economy. From this perspective, the Italian hop sector can be understood as an emerging system in which competitiveness depends not only on production efficiency but also on the ability to valorise context-specific characteristics. Italian pedoclimatic conditions can support the production of hops with distinctive sensory profiles that differ from standardised international references. This differentiation may represent a strategic asset, fostering product innovation and supporting the emergence of beer styles more closely linked to local identity. In this way, new hop profiles may gradually be reinterpreted as a source of differentiation, contributing to breaking down cultural barriers. However, these cultural barriers, combined with the lack of clear regulations on origin labelling, increase market risk and reduce the propensity for large-scale investment by local producers. Cluster 2 farms seem to mitigate these weaknesses through targeted investments in post-harvest technology, professional sensory testing, and the creation of direct relationships with breweries, ensuring consistent quality. This highlights a trade-off in strategic positioning: diversification helps reduce risk where demand is uncertain and poorly differentiated, but it can also limit the ability of farms to achieve higher margins through specialisation and quality-based strategies.

These dynamics can also be interpreted in light of a form of technological and cultural lock-in within the craft beer industry. Even with a focus on diversity, most brewing remains

tied to international styles that demand very specific, standardised hop profiles. This creates a rigid market where domestic hops may struggle to fit traditional recipes without significant adaptation. On top of these market hurdles, institutional gaps—specifically the lack of registered plant protection products—continue to act as a major bottleneck. To effectively overcome these technical and market barriers, policy interventions should focus on three key areas. First, accelerating the registration of hop-specific plant protection products is essential to reduce agronomic uncertainty, especially for organic growers. Second, public funding should prioritise shared, small-scale processing infrastructure—such as drying and pelletising hubs—to help smaller farms bypass critical post-harvest bottlenecks. Finally, updating the legal definitions of agricultural and craft beers to require a minimum quota of domestic hops could be a highly effective measure. Tying these premium designations directly to the use of local raw materials would naturally boost domestic demand and foster stronger, long-term partnerships between growers and breweries. Consolidating this sector will require a synchronised evolution of agronomy, supply chain governance, and market demand; without this coordination, hop farming risks remaining a high-barrier niche for a select few rather than a resilient, widespread system.

Consequently, policy interventions should be diversified and tailored to different types of farms, although their effectiveness is likely to depend on the initial structural conditions of each farm, rather than adopting a uniform approach. This implies that similar measures may produce heterogeneous outcomes, as farms differ in their level of specialisation, technical capacity, and degree of integration within the supply chain. However, certain structural constraints affect the entire sector independently of the type of farm. In particular, the absence of an adequate regulatory framework for plant protection products is a major constraint on the development of the sector, because access to technical inputs is a fundamental prerequisite for increasing hops UAA and ensuring crop profitability. Farms in Cluster 3, which often involve new operators, need to strengthen their technical base. Priority actions, therefore, include the possibility of using shared post-harvest infrastructure and access to targeted technical training programmes, especially during the start-up phases of cultivation. With regard to farms in Cluster 1, the main objective of interventions should be to strengthen demand. For example, clearer origin labelling criteria could improve the promotion of Italian hops, while support for short supply chains could improve price stability. Cluster 2 farms, which are more advanced, would benefit from measures to protect their investments in quality, such as certification systems and advanced traceability systems.

Beyond the specific needs of the clusters, there is a transversal requirement to strengthen producer aggregation. Greater cohesion through consortia could improve the perception of Italian hops, facilitate the sharing of standards, enable the exchange of knowledge, and improve the sector's ability to interact with policymakers. Ultimately, these findings highlight that promoting hops exclusively as a diversification strategy, without addressing fundamental structural issues such as scale, mechanisation, and supply chain governance, can lead to suboptimal resource allocation for unprepared farms.

The challenges identified across the different farm profiles also point to several directions for future research. As the industry matures, expanding the sample size will allow for more robust, longitudinal tracking of farm trajectories. Future studies would also benefit from deeper qualitative work, such as multiple case studies or interviews throughout the entire supply chain, to better grasp the strategic nuances at play. Furthermore, from a broader perspective, the hop and beer supply chain presents relevant opportunities for technological integration and circular economy practices. While digitalisation and precision monitoring represent a crucial frontier for optimising crop management, hop cultivation generates post-harvest biomass, and the brewing process produces by-products such as

spent grains. Both could be valorised within integrated and sustainability-oriented production systems. These dynamics extend beyond hop cultivation to the broader brewing supply chain, including upstream activities such as barley production and malting, and raise relevant issues related to environmental sustainability, supply chain coordination, and the adoption of circular economy practices. Drawing on recent insights from Boincean et al. [49] and Honcharuk et al. [50], an analysis of integrated Environmental, Social, and Governance (ESG) models and regenerative agriculture can be highly applicable to the Italian brewing industry. This perspective implies integrating ESG-oriented criteria across the entire supply chain, from agronomic practices in barley cultivation to processing activities in malting and brewing. In this regard, recent Life Cycle Assessment (LCA) evidence highlights the dominant role of the agricultural phase in determining the environmental impact of malt production, suggesting that the selection of suppliers adopting sustainable practices can significantly reduce environmental pressures while enhancing the overall resilience and competitiveness of the sector [50,51]. This includes improvements in agronomic practices, resource efficiency, and the circular management of by-products, contributing to more sustainable and integrated production systems.

## 5. Conclusions

The study brings to light the deep structural and economic diversity within Italy's burgeoning hop sector, proving that long-term viability is inseparable from sound technical and organisational choices. By mapping out three distinct farm profiles—ranging from highly specialised, high-performing leaders to diversified producers and more vulnerable, volatile operations—the analysis illustrates the varied contexts in which hop farming can truly thrive. By identifying distinct economic strategies and farm typologies, the analysis also clarifies how different structural and organisational configurations influence farm viability within this emerging sector. These findings offer a dual benefit: they provide farmers with a practical perspective on stabilising income through diversification while simultaneously offering policymakers a foundation for targeted sectoral growth. Ultimately, the cultivation of hops represents a real opportunity to anchor farms more firmly within local agri-food networks.

The identification of three distinct farm typologies suggests the need for differentiated policy interventions, further supported by the evidence and insights provided by the roundtable discussion. Diversified farms (Cluster 1) appear to benefit from stronger demand-side conditions, including improved market recognition of domestic hop quality and the development of short supply chains, which may help reduce price uncertainty. Highly specialised farms (Cluster 2) are more closely associated with strategies based on quality enhancement, innovation, and deeper integration within the supply chain, which support their competitive positioning. In contrast, underperforming farms (Cluster 3) highlight the importance of technical assistance, access to shared infrastructure, and support during the initial phases of production, where economic vulnerability is highest.

These patterns are also influenced by demand-side constraints within the brewing sector, which may limit the adoption of domestic hops despite their technical potential.

Given the limited sample size and potential lack of representativeness, the objective of this study is not to draw inferential conclusions about the broader population of Italian hop producers. Rather, it aims to identify recurring economic strategies, classify farms into functional typologies, and analyse the positioning of a highly specialised case-study farm. This focus reflects the nature of the available data and is consistent with previous research conducted in niche agricultural contexts.

Despite the positive momentum, the Italian hop industry remains heavily dependent on specialised supply chain intermediaries. These players are vital for bridging the gap

between the field and the brewery, as they manage everything from post-harvest processing to standardisation and quality control. Without them, direct dealings between growers and brewers are often plagued by uncertainty and weak contracts, which ultimately threaten the financial survival of the farm. This highlights the importance of stronger coordination mechanisms along the supply chain to reduce structural barriers and improve market integration. This also points to the relevance of cross-cutting structural issues, including regulatory constraints and the limited availability of specific technical inputs, which affect farms across different profiles.

From an agronomic perspective, hop cultivation follows a well-defined development pattern: yields are typically negligible in the first year due to root system establishment, increase significantly from the second year, and reach full capacity from the third year onwards. This implies that the first year represents a transitional phase with limited or no economic return, while subsequent years allow for more stable and representative production levels [52]. However, information on the age of hop plantations is not available within the FADN dataset used in this study and could therefore not be directly included in the empirical analysis. Nevertheless, given the panel structure of the data, which includes repeated observations over a three-year period for the same farms, it can be reasonably assumed that the analysed farms had an established hop cultivation system for at least three years. As a result, the observed production levels are likely to reflect farms operating beyond the initial establishment phase, where yields are typically still negligible.

While this research provides a fresh microeconomic look at the sector, it is not without its limitations. The 13-farm sample accounts for roughly 19% of the national area, yet it may not reflect the full geographical or structural variety of Italy. The 2021–2023 timeframe also captures a specific post-pandemic recovery window and may not fully account for long-term investment cycles. Additionally, the use of FADN data implies a focus on economic metrics at the expense of detailed agronomic variables like varietal choice or specific pest management, which could further explain income variability. Methodologically, our use of PCA and fuzzy clustering should be seen as a way to generate hypotheses rather than provide definitive proofs.

Future research could further explore broader supply chain dynamics and sustainability dimensions, including digitalisation and circular economy practices within the hop-beer system.

Overall, these findings highlight that the economic viability of hop cultivation in Italy depends less on the crop itself and more on the alignment between technical capacity, organisational choices, and supply chain integration. In this perspective, the study provides a first empirical basis for understanding the development trajectories of this emerging sector and for supporting more targeted and context-sensitive policy interventions.

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## Abbreviations

The following abbreviations are used in this manuscript:

CAP	Common Agricultural Policy
EU	European Union
FADN	Farm Accountancy Data Network
FSDN	Farm Sustainability Data Network
GM	Gross Margin
GM_cv	Coefficient of Variation in Gross Margin
GM_sd	Standard Deviation of Gross Margin
PCA	Principal Component Analysis
Q_HOP	Hop Output (quintals)
SH	Specialisation Ratio
SO	Standard Output
UAA	Utilised Agricultural Area
VCs	Variable Costs

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