Land Structure as a Determinant of Legal Entity Dairy Farm Typologies: Evidence from Croatia

Struktura zemljišta kao determinanta tipologije pravnih subjekata na mliječnim farmama: dokazi iz Hrvatske

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Poljoprivreda / Agriculture

ISSN: 1848-8080 (Online)
ISSN: 1330-7142 (Print)

https://doi.org/10.18047/poljo.32.1.13

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ISSN 1330-7142
UDK=631.41:631.1.017.1-047.44(497.5)
https://doi.org/10.18047/poljo.32.1.13

LAND STRUCTURE AS A DETERMINANT OF LEGAL ENTITY DAIRY FARM TYPOLOGIES: EVIDENCE FROM CROATIA

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Original scientific paper

Izvorni znanstveni članak

SUMMARY

The paper presents the results of a cluster analysis conducted on all 62 legal dairy farms in Croatia. The aim is to group legal entity dairy farms into smaller homogeneous groups with similar characteristics according to a given variable. Such farm groups will serve to define typical farms that will be the basis for an in-depth assessment of the current state and further development of the Croatian dairy sector. The four key variables used in the cluster analysis relate to the structure of the total utilized agricultural area (UAA). The cluster analysis identified five different groups of legal dairy farms, and 90% of legal dairy farms belong to a cluster of medium-sized farms with strong development potential. It was shown that on legal dairy farms, agricultural land is mainly arable, with corn as the main crop. They show a highly specialized structure focused almost exclusively on field crops, unlike family dairy farms that show greater diversification (meadows, grasslands, karst pastures). Based on these findings, the development of farm models using mathematical programming is planned. The analysis relies on real sector data provided by the Croatian Agriculture and Food Agency and was conducted using hierarchical and non-hierarchical clustering methods in IBM SPSS Statistics. The results provide a solid basis for designing farm-level models and contribute to future research and evidence-based policymaking in the Croatian dairy sector.

Keywords: land structure, legal dairy farms, cluster analysis, farm model

INTRODUCTION

Across the European Union (EU), including Croatia, a decline in the number of dairy farms, livestock and total milk production has been observed (Figure 1, Ministry of Agriculture, Forestry, and Fisheries of the Republic of Croatia, 2024). This situation reflects a broader consolidation trend typical of the agricultural sector (Gonzalez-Mejia et al., 2018). At the same time, milk yield per cow has increased, mainly due to the adoption of new technologies (Mijić et al., 2021). Small farms have been particularly affected, often shifting to agribusiness production, while larger farms have shown only modest production growth (Očić et al., 2023). Given this situation and the limited effectiveness of current policy measures, a comprehensive sectoral analysis and the formulation of more effective recovery strategies are needed.

In this context, decision support models are essential as they provide deeper insights into farm performance and facilitate evidence-based policymaking (Ciaian et al., 2013). Within the EU's Common Agricultural Policy (CAP), strategic planning increasingly relies on simulation models at both the farm and aggregate levels to form policy decisions (Lovec et al., 2020). While detailed analysis at the level of each individual farm is not feasible, the development of a representative farm model for Croatian dairy farms began by classifying farms according to common shared characteristics and production capacities. In this way, representative typical dairy farms can be defined. In our case, a farm is considered a dairy farm if it keeps dairy cows and delivers milk. This excludes farms that keep dairy cows but do not deliver milk, which in practice corresponds to a suckler cow production system. Consequently,

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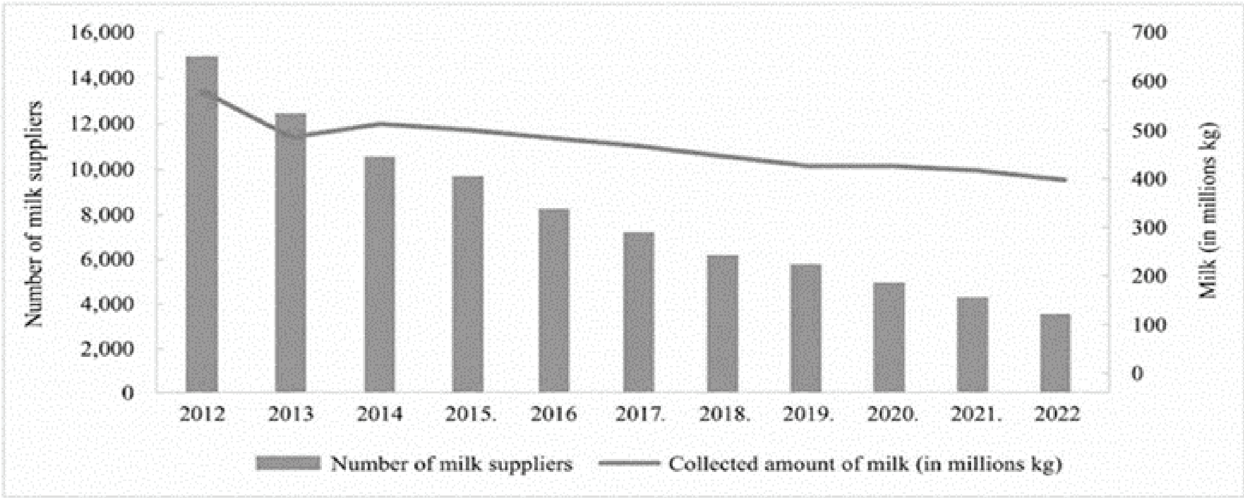


Figure 1. Number of milk suppliers and collected amount of milk by year in the Republic of Croatia.
Grafikon 1. Broj isporučitelja mlijeka i otkupljene količine mlijeka po godinama u Republici Hrvatskoj.

farms should be grouped into smaller homogeneous categories of similar attributes, commonly referred to as typical farms (Alvarez et al., 2018). Cluster analysis is frequently employed to identify such representative or so-called typical farms. However, the results of cluster analysis are not definitive, as they depend on numerous methodological choices, including the selection between hierarchical and non-hierarchical techniques, as well as specific approaches within hierarchical clustering. It is important to notice that the results are also influenced by the variable selection, which determines the criteria of similarity and thus the structure of the resulting clusters. To ensure that the resulting clusters possess statistical reliability and analytical value, variables must be carefully aligned with the research objective. Therefore, agricultural land, which is not only the primary source of animal feed but also a fundamental determinant of the economic profitability and ecological sustainability of the farm, is one of the logical choices for the variables. It is also an essential production resource for the dairy sector, as it defines the intensity of production and the long-term sustainability of the farm. The allocation between arable land, permanent grassland, and pasture directly affects feeding strategies, ecological footprint, and economic efficiency.

Wilkinson et al. (2020) emphasized that achieving an optimal balance between arable land and pasture is crucial to maximizing milk production while reducing feeding costs. According to the author, a daily grass intake in intensive grazing systems of 20–30 kg DM/cow enables high milk yields, improved pasture utilization, and a more favorable milk composition, while reducing feeding costs. Similar studies have confirmed that increased use of pasture per hectare directly enhances both gross and net yields (Shalloo et al., 2004; Finneran et al., 2010; Bórawski et al., 2020; Pečnik et al., 2022). Delaby et al. (2020) highlighted three defining aspects of pasture-based feeding systems. Pasture-based systems have more positive aspects in producing healthy food than systems based on feeding livestock with conserved forage. Farmers should be encouraged by financial signals from the market and guided to switch to pasture-based systems with the help and support of agricultural policy. In contrast, arable land offers higher productivity per unit area than grassland, but it competes for land used for human food production, thereby generating environmental and social trade-offs (Ineichen et al., 2023). These aspects underscore the importance of maintaining a balanced relationship between pasture and cropland, with pastures providing natural grazing and encouraging animal movement, while cropland provides a stable supply of nutrient-rich forage crops. Since land use strategies directly affect herd nutrition and manure management, they need to be designed in line with sustainability principles, while also addressing food security and environmental protection goals (Sanderson et al., 2009; Martin et al., 2017).

Accordingly, this paper presents the results of a descriptive analysis of agricultural land areas and land-use structure of dairy farms operated by legal entities in the Republic of Croatia. As previously noted, the area of agricultural land available to a dairy farm determines the extent of feed that can be produced on farm, which directly affects the number of cows that can be sustained without additional costs for the purchase of cow feed. Larger areas of agricultural land allow for greater self-sufficiency and profitability of production. Furthermore, this paper presents the results of a cluster analysis conducted on a set of variables related to the agricultural land use patterns of dairy farms owned by legal entities. A similar analysis was employed by Petrač et al. (2025) who identified the size and structure of agricultural land on Croatian family dairy farms, emphasizing their primary function. Here, particular attention is again paid to assessing the share of land allocated to pastures versus arable land for crop production, as well as to identifying the dominant forage crops used in livestock feeding. This analysis provides an overview of the distribution and use of agricultural land on legal dairy farms in Croatia. This is also a key factor in assessing technological practices and the efficiency of food production. The cluster analysis methodology is applied to provide a deeper understanding of structural differences, levels of specialization and economic performance across organizational forms. Special attention is paid to the comparative analysis of the results obtained for family dairy farms (Petrač et al., 2025) and legal entities, with an emphasis on their primary functions and production orientations. This classification allows for the analysis of the interrelationships between arable land and pastures, as well as the dominant forage crops grown on family and legal dairy farms. This establishes an analytical framework for assessing the efficiency and sustainability of the Croatian dairy sector. The resulting clusters will serve as a preliminary step toward defining representative types of dairy farms that integrate land-use characteristics, production parameters, and technological attributes. To further develop and implement a microsimulation tool based on mathematical programming specifically, a Bioeconomic Farm Model (BEFM), following the example of the Slovenian SiTFarm model (Žgajnar et al., 2022)—the final farm types will be validated and refined through expert workshops with consultants and sector specialists. The contribution of the study is reflected in (i) the analysis of the complete population of legal dairy farms in Croatia, (ii) the application of cluster analysis based on land use structure, (iii) the identification of five farm types, with a predominant share of medium-sized farms, and (iv) the development of representative farms for future farm modelling purposes. Accordingly, the study thus goes beyond a descriptive approach and provides a basis for modelling the future development of the sector.

MATERIALS AND METHODS

Data and Descriptive Statistics

The dataset covers all agricultural holdings in Croatia that supply milk and thus represents farm-level data for the entire dairy sector. The database, compiled in 2022, includes all registered agricultural holdings in the Republic of Croatia that are engaged in milk production, as well as general data about the farm itself (such as location, number of cows, amount of milk produced, land area, crop structure).

The initial database consisted of 4,198 registered dairy farms. Following thorough data cleaning and reconciliation procedures (e.g., removal of duplicate identifiers, double entry, and erroneous records), the final dataset comprised 3,393 valid observations. Of these, 3,331 were classified as family farms, while 62 were registered as legal entities.

Statistical processing was performed in IBM SPSS Statistics, version 22.0, focusing on the 62 legal entity farms. Descriptive statistics for the variables used in the cluster analysis are presented in Table 1. In contrast to the previous cluster analysis of 3,331 family dairy farms (Petrač et al., 2025), which applied the same set of quantitative variables, this study focuses specifically on legal entity dairy farms. The variables analyzed include arable land for growing crops, pastures for grazing cows, meadows, and land for other purposes (e.g., vineyards, orchards, nurseries) (Table 1). For each variable, key descriptive statistics were calculated: mean, standard deviation (SD), minimum (Min), maximum (Max), and interquartile range (Q1–Q3), as shown in Table 2.

Table 1. List of variables

Tablica 1. Popis varijabli

Variable / *Varijabla*	**Variable name** / *Naziv varijable*
Meadow land (ha) / *Livadno zemljište (ha)*	ML
Pastureland (ha) / *Pašnjak (ha)*	PL
Arable land (ha) / *Obradivo zemljište (ha)*	AL
Land for other purposes (ha) / *Zemljište za druge namjene (ha)*	OL

Table 2. Descriptive statistics for legal dairy farms in ha

Tablica 2. Deskriptivna statistika za mliječne farme pravnih osoba u ha

Variable name / *Naziv varijable*	**Mean** / *Prosjek*	**SD** / *Standardna devijacija*	**Min.** / *Minimum*	**Max.** / *Maksimum*	Q1	Q2	Q3
ML	3.22	7.98	0.00	47.49	0.00	0.00	2.11
AL	2,006.87	12,542.41	0.00	98,226.94	25.18	83.44	306.78
PL	12.83	48.19	0.00	330.25	0.00	0.00	2.22
OP	53.26	364.51	0.00	2,863.45	0.00	0.00	0.00

The first, second, and third quartiles for "Land for other purposes" are equal to zero ($Q_1 = Q_2 = Q_3 = 0$), indicating that at least 75 % of all observed legal entity dairy farms do not possess such land. The interquartile range further confirms minimal variability in the lower part of the distribution.

Similarly, for land used as pastures and meadows, the first and second quartiles are zero, meaning that at least half of the legal dairy farms have no such areas. In contrast, the mean area of arable land among legal entity dairy farms is 2,006.87 ha, with a maximum value of 98,226.94 ha, confirming that these farms are predominantly oriented toward arable land use.

Cluster Analysis

Cluster analysis was carried out using the IBM SPSS Statistics, V22.0, incorporating all variables previously described. Hierarchical (agglomerative) clustering was first conducted using Ward's minimum variance method. In this approach, each legal dairy farm initially represents an individual cluster. At the first step, the two most similar legal dairy farms are merged into a single cluster. Subsequently, either a new farm is added to an existing cluster, or another pair of farms is combined. This iterative process continues based on pairwise similarities until all observations are grouped into one overall cluster. The basis of this method is a similarity (or distance) matrix, which records pairwise relationships among all legal entity dairy farms. The matrix is symmetric, with dimensions corresponding to the number of observations.

Ward's method minimizes the total within-cluster variance by merging clusters that result in the smallest possible increase in the overall sum of squared differences, thereby ensuring maximum internal homogeneity. The results of both agglomerative and divisive clustering can be effectively visualized by means of a two-dimensional hierarchical diagram, commonly referred to as a dendrogram, which graphically illustrates the relationships and distances between clusters.

Following the hierarchical procedure, non-hierarchical clustering was performed using the k-means algorithm (Scitovski et al., 2022). The k-means method belongs to the class of optimization-based non-hierarchical clustering methods that allow iterative reassignment of objects. In this procedure, legal dairy farms are organized into a predetermined number of clusters (k) and then are iteratively reassigned until a specified numerical criterion is met. The fulfilment of this criterion is directly linked to the objective of cluster analysis, which consists of obtaining the most compact and well-separated clusters. Accordingly, the goal is to minimize the distance between objects within clusters and maximize the distance between clusters themselves.

The squared Euclidean distance was employed as the distance metric, defined as:

$$d(x,y) = \sum_{i=1}^{n} (x_i - y_i),^2$$

where $x, y \in S$, S is the data set, $x = (x_1, x_2, \dots, x_n)$ and $y = (y_1, y_2, \dots, y_n)$, $n \in \mathbb{N}$, and x_i, y_i, $\forall i \in \{1,2,\dots,n\}$, are numeric variables.

All algorithms were applied to standardized z-scores so that all variables had equal weight in the cluster analysis. Let $x^{(1)}, x^{(2)}, \dots, x^{(n)} \in S$ be any objects, $x^{(j)} = (x_1{}^{(j)}, x_2{}^{(j)}, \dots, x_k{}^{(j)})$, and any $1 \le k \le n$. Z-score is calculated by the formula

$$z_k = \frac{x_k{}^{(j)} - \mu_k}{\sigma_k} \quad , \qquad 1 \le j \le n,$$

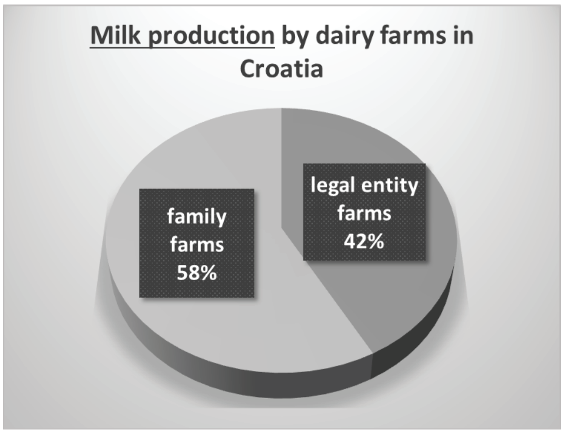
where μ_k is the arithmetic mean and σ_k is the standard deviation (Sabo et al., 2010).

Among several generated solutions, the one most suitable for further analysis was selected. The optimal number of clusters was determined through visual interpretation of the dendrogram and subsequently used as an input parameter in the k-means procedure.

RESULTS AND DISCUSSION

In 2022, dairy farms in Croatia delivered a total of 420,926,579.57 kg of milk, making a significant contribution to national milk production. The analysis by ownership type reveals significant differences between family farms and legal entities in both production capacity and land use structure.

Family dairy farms, which constitute the majority of producers, delivered 244,021,361.81 kg of milk, accounting for 58 % of national production (Petrač et al., 2025). The average milk delivery per farm was 73,257.69 kg, and the total utilized agricultural area (UAA) covered 78,885.98 ha, corresponding to 38 % of the total land used by the dairy sector. By contrast, legal entities dairy farms represent only 62 large producers, and in 2022, they accounted for 42 % of the total milk supply (180,905,217.8 kg) and cultivated 128,723.74 ha of agricultural land, which corresponds to 62 % of the total UAA used by dairy farms in Croatia (Figure 2). Their concentration of land resources enables more efficient use of agrotechnical measures, greater adoption of modern technologies, and more rational resource management, thereby contributing to higher productivity and system stability.



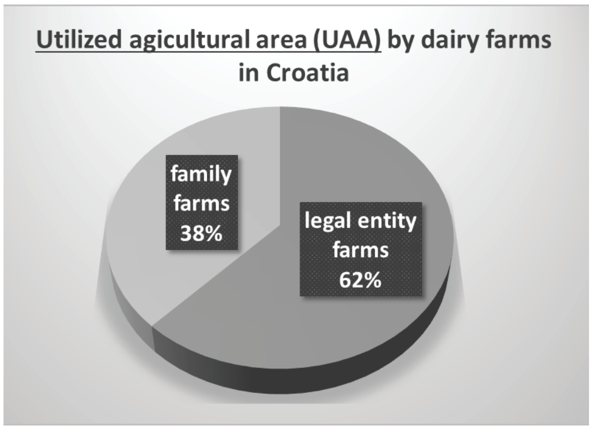


Figure 2. Share of family and legal entity dairy farms in total milk production (on the left) in Croatia and total UAA in 2022 (on the right).

Grafikon 2. Udio obiteljskih mliječnih farma i mliječnih farma pravnih osoba u ukupnoj proizvodnji mlijeka u Hrvatskoj (lijevo) i ukupnome korištenju poljoprivrednoga zemljišta 2022. godine (desno).

On family dairy farms, arable land predominates, covering 81.37 % of the total UAA, followed by meadows at 13.12 % and continental grasslands at 2.85 %. Most of this land is located in Pannonian Croatia (HR NUTS 2), reflecting its favorable agroecological conditions and high agricultural potential. Among arable crops, maize dominates (44 %), reflecting its crucial role in fodder and silage for the winter feed of dairy cows. Other main crops include winter wheat (12 %), grasses and forage crops (10 %), alfalfa (9 %), and winter barley (5 %), providing basic food diversity (Petrač et al., 2025). Limited crop diversification, characterized by monocultures and simple rotations, however, increases vulnerability to climate variability. Grasslands play an increasingly important role in enhancing system resilience and agroecosystem diversification (Sanderson et al., 2009). Arable land is also predominant on legal dairy farms, covering as much as 96.66 % of the total utilized area (UAA), followed by vineyards with 2.55 %, meadows with 0.62 %, pastures with 0.16 %, and others with 0.01 %. Most of this land (98 %) is located in Pannonian Croatia (HR NUTS 2), reflecting its favorable agro-ecological conditions and high agricultural potential (Table 3).

Table 3. Distribution of land by purpose and NUTS regions of legal entity dairy farms

Tablica 3. Raspodjela zemljišta prema namjeni i NUTS regijama mliječnih farma pravnih osoba

NUTS2	NOC	%	ML (ha)	AL (ha)	PL (ha)	OP (ha)	AUC (ha)	%
Legal entity dairy farms (n = 62)								
City of Zagreb	137	1%	0	105.25	0	0	105.25	0%
Pannonian Croatia	19,430	93%	123.39	122,432.88	469.09	3258.71	126,284.06	98%
Northern Croatia	424	2%	28.24	378.48	3.22	6.21	416.15	0%
Adriatic Croatia	949	4%	48.27	1509.51	323.36	37.14	1,918.28	2%
Total	20,940	100%	199.9	124,426.12	795.67	3,302.06	128,723.74	100%

Legend: NOC-Number of cows, AL-arable land for growing crops, PL-pastureland designated for cow grazing, ML-meadow land, OP- agricultural land for other purposes, AUC-Area under culture / *Legenda: NOC – broj krava, AL – obradivo zemljište za uzgoj usjeva, PL – pašnjak namijenjen ispaši krava, ML – livadno zemljište, OP – poljoprivredno zemljište za druge namjene, AUC – površina pod kulturom / obrađena površina.*

On legal dairy farms (Figure 3), corn dominates among field crops, 47,995.32 ha (37 %), mainly for silage production. Large areas are also occupied by winter wheat (26,606.38 ha; 21 %), winter barley (10,879.98 ha; 9 %), soybeans (10,082.64 ha; 8 %), and sugar beet (9,703.14 ha; 8 %). The basis of animal feed production is forage crops such as alfalfa, clover, and grass, and more is focused on growing field crops that have a high market value.

In general, agricultural land in Croatia - both on family farms and on legal farms - is mostly arable, with maize as the main crop. Family dairy farms, however, show greater diversification (meadows, grasslands, karst pastures), while legal entity dairy farms show a highly specialized structure focused almost exclusively on arable crops. These differences reflect different production strategies: family dairy farms tend to be mixed in order to ensure food self-sufficiency, while legal entities tend to engage in intensive, market-oriented crop production.

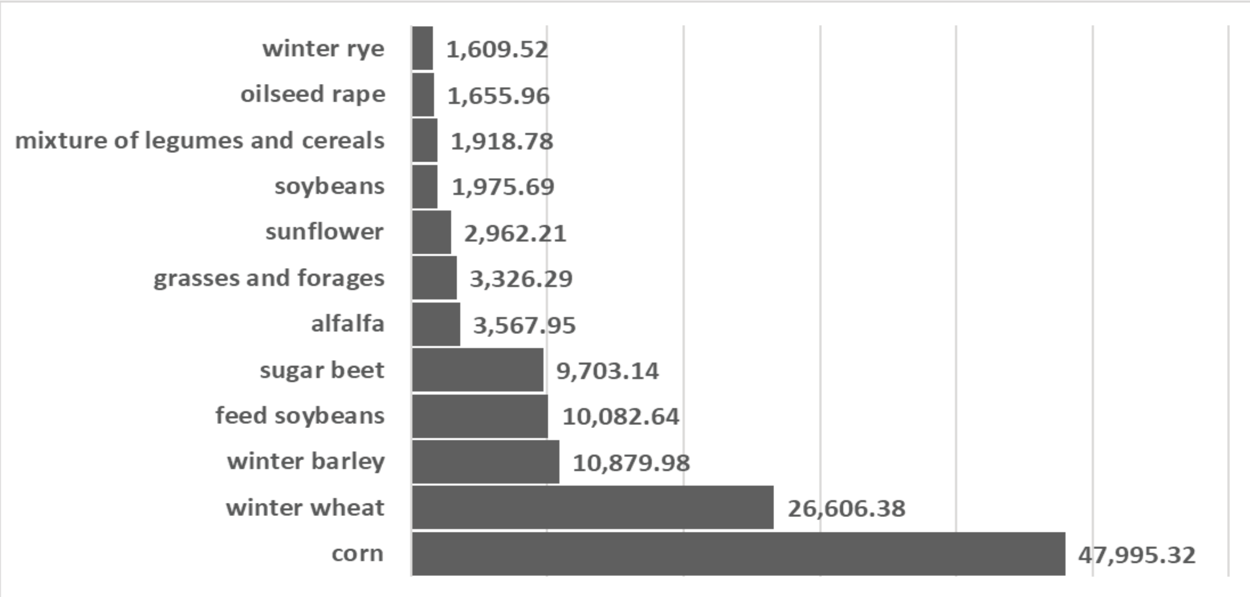


Figure 3. Crop distribution on arable land of legal entity dairy farms.

Grafikon 3. Raspodjela usjeva na oranicama mliječnih farmi pravnih osoba.

Such specialization can have environmental drawbacks, including soil depletion, higher use of mineral fertilizers and pesticides, and reduced biodiversity (Wivstad et al., 2023). Rolando et al. (2025) also noted that intensive organic systems, although more productive, rely more on external food and have a larger ecological footprint. In contrast, systems that use pastures preserve biodiversity and the landscape, thereby contributing to the stability of agroecosystems (Poetsch, 2007; Kellermann et al., 2014). Pasture-based systems simultaneously consider animal welfare and the quality and efficiency of work (Dillon et al., 2005; Peyraud et al., 2010). According to some authors (Shalloo et al., 2011; Creighton et al., 2011), there is still room for improvement in the management of pasture growth and utilization. McDowell et al. (2022) demonstrated that a combination of restricted grazing periods and adequate housing can reduce nutrient losses, particularly of nitrogen and phosphorus, while improving feed control. However, such systems are costlier and may constrain natural animal behavior. Meanwhile, the use of marginal lands unsuitable for arable production, such as peat or upland soils, offers opportunities to expand the production base and utilize otherwise idle resources (Wilkinson et al., 2021). In organic systems, integrating arable land and permanent grassland enhances self-sufficiency and reduces dependence on external inputs (Wallenbeck et al., 2018).

Cluster Analysis

The hierarchical cluster analysis of legal entity dairy farms is illustrated in Figure 4. The dendrogram shows how legal entity dairy farms group according to similarities in land use characteristics. Based on the dendrogram, a five-cluster solution was found to best capture the diversity among legal entity dairy farms. The subsequent k-means clustering confirmed these five groups, and for each cluster, we identified the number of farms, membership composition, and average land-use characteristics (meadows, pastures, arable land, and other categories). This allows us to see how land is represented in the different groups, which is the primary goal of this analysis.

For comparison, a similar analysis conducted on family dairy farms (Petrač et al, 2025) identified 15 clusters. Most farms (77 %) are significantly smaller than the national average, with 9.95 cows and 12.79 ha of land, forming the largest cluster. The second-largest cluster comprises 436 farms (13 %), owning more agricultural land (48.87 ha, 28.7 cows), but probably focusing less on dairy production. The cluster that exceeds the national averages in all key indicators, with 67.3 cows, 147.33 ha of land, and a milk yield of 6,538 kg per cow, belongs to the cluster containing 2 % of dairy farms. This cluster reflects high specialization and development potential—consistent with findings for Slovenian dairy farms (Žgajnar et al., 2024). The findings show that family dairy farms in Croatia, as well as in the EU (Parzonko et al., 2024), have significant diversity in scale and production technology.

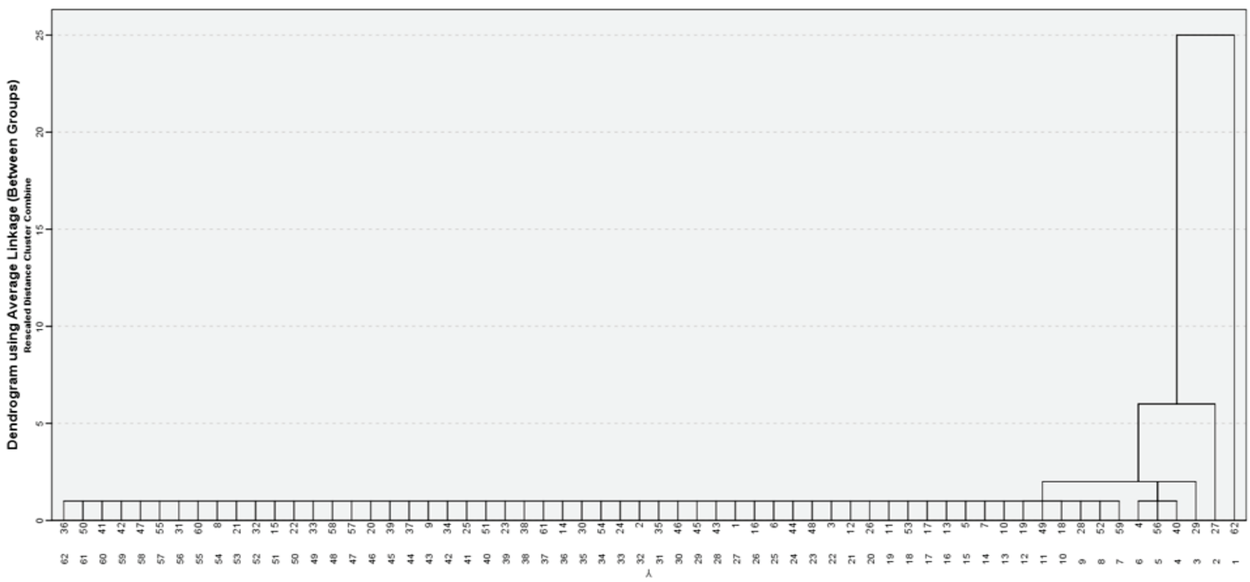


Figure 4. Dendrogram of legal entity dairy farms according to variables (ML, AL, PL, OP).
Figure 4. Dendrogram mliječnih farma pravnih osoba obzirom na varijable ML, AL, PL, OP.

Within legal entities, the k-means results (Table 4) show that 56 farms (90 %) fall into Cluster 1, the largest group. The average number of cows per farm in this cluster (283 dairy cows) is lower than the national average in the Republic of Croatia (338), and the average area under cultivation (448.1 ha) is also below the national average of 2,076.2 ha. Similarly, the average areas of meadows, arable land, pastures, and other types of land (1.3 ha, 437.2 ha, 1.7 ha, 7.8 ha) are smaller than the corresponding national averages (3.2 ha, 2,006.9 ha, 12.8 ha, 53.3 ha). However, the number of crops grown on these dairy farms (21) exceeds the national average (6), indicating that the majority of legal dairy farms are mainly composed of small to medium-sized farms with limited arable land, meadows, and pastures, but higher crop diversity - suggesting flexibility and adaptive potential. When the largest farm (Cluster 3), identified as a distinct outlier, is excluded from the analysis, the overall average values become higher. After excluding this extreme case, it can be concluded that Cluster 1 actually includes medium-sized farms with significant development potential.

Cluster 2 includes only three farms (5 %), structurally similar to Cluster 1, but with significantly larger meadow and pasture areas. On average, these farms have 55.8 hectares of meadows and pastures, thus falling into the category of farms that play an important role in maintaining grassland-based production systems and contributing to sustainable agricultural land management and biodiversity conservation. Extensive grassland enables cost-effective feed production, reduces dependence on purchased feed, and improves the nutritional quality of milk thanks to a higher proportion of fresh roughage in the cow's diet. In addition to the economic benefits, such farms contribute to the preservation of biodiversity, soil fertility, and landscape diversity, while promoting carbon sequestration and mitigating the impact of climate change. From an ecological and socio-economic point of view, grassland-based livestock farms are of paramount importance for the preservation of traditional livestock production systems, especially in less-favored or marginal rural areas. In this way, they contribute to the sustainability of rural areas and the preservation of both ecological and socio-economic vitality.

Cluster 3 is the largest legal entity dairy farm in Croatia, with 101,427.9 ha of arable land for maintaining a herd of 4,051 cows, located in Pannonian Croatia.

Clusters 4 and 5 represent isolated cases, being individual farms with a large share of arable land, a small number of cows, and a relatively low average milk production per cow, which limits their possibilities for the larger investments needed for further growth and development.

The occurrence of clusters containing a single farm is a consequence of extreme outliers in the data (i.e., farms with very large land areas or a large number of cows). Their separation into distinct clusters results from the clustering method employed (hierarchical clustering and k-means), which groups units according to the similarity of the observed variables.

Table 4. Cluster structure legal dairy farms

Tablica 4. Struktura klastera mliječnih farma pravnih osoba

	Average / *Prosjek*								
Cluster / *Klaster*	NOF	NOC	ML	AL	PL	OP	NOPC	AUC	Yield per cow
Unit of measurement / *Mjerna jedinica*			ha	ha	ha	ha		ha	kg/cow
1	56	283	1.3	437.2	1.7	7.8	21.0	448.1	6,499.0
2	3	311	23.7	551.1	32.1	0.00	7.0	606.9	5,722.8
3	1	4,051	7.3	98,226.9	330.3	2,863.5	5.0	101,427.9	8,541.4
4	1	47	47.5	55.8	111.9	0.0	10.7	215.2	6,787.2
5	1	68	0.6	4.9	160.0	0.0	5.6	165.5	5,545.9
Grand total / *Ukupno*	62	338	3.2	2,006.9	12.8	53.3	6.1	2,076.2	6,483.7

Legend: NOF-Number of farms, NOC-Number of cows, AL-arable land for growing crops, PL-pastureland designated for cow grazing, ML-meadow land, OP- agricultural land for other purposes, NOPC-Number of plant cultures, AUC-Area under culture / *Legenda: NOF – broj farmi, NOC – broj krava, AL – obradivo zemljište za uzgoj usjeva, PL – pašnjak namijenjen ispaši krava, ML – livadno zemljište, OP – poljoprivredno zemljište za druge namjene, NOPC – broj biljnih kultura, AUC – površina pod kulturom / obrađena površina.*

CONCLUSION

This paper analyses Croatian dairy farms operating as legal entities, highlighting the importance of land use as a criterion for classifying and assessing sustainability. Despite the continuous decline in the total number of dairy farms and milk production at the national level, 62 active legal farms still exist, although they are often limited by land and production capacity. A cluster analysis identified five different groups of legal dairy farms. The largest number of legal entity farms (90%) belong to the cluster of medium-sized farms with strong development potential. These are legal entity farms characterized by better capital equipment, organizational efficiency, and market adaptability.

The results of the cluster analysis indicate a structural segmentation of the Croatian legal dairy farm sector. The sector is predominantly composed of medium-sized farms that exhibit substantial potential for economies of scale, productivity enhancement, and improved market integration. In addition, several atypical dairy farm types were identified, which differ in scale, production organization, and technical efficiency, which points to marked heterogeneity in economic performance across the sector. This heterogeneity of dairy farms indicates the need for targeted economic and agricultural policies that differentiate support instruments according to the specificities of individual segments (e.g., targeted investment incentives for viable growth-oriented farms, restructuring measures to enhance competitiveness, and carefully designed exit strategies for persistently inefficient farms). The established typology of dairy farms will be used operationally as an analytical basis for the development of a representative economic model, enabling more precise simulation of resource allocation and long-term design of sustainable strategies within the Croatian dairy sector.

Based on these findings, a foundation has been established for the detailed definition of typical farm models. Accordingly, five representative farm types will be developed for legal entity dairy farms. Furthermore, through expert workshops, technological parameters and production system characteristics will be defined and validated. As a result, it is expected that Cluster 1 will be further subdivided into several subtypes, primarily differentiated by production technologies, intensity levels, breed composition, herd replacement strategies, and other management factors.

The comparative analysis conducted showed differences in the use and structure of agricultural land between family dairy farms and legal entity dairy farms. The same analysis showed that maize is the main crop in both categories. This difference presents both opportunities and risks. Overreliance on monocultures, especially maize and wheat, increases the vulnerability of the system to climate change, pests, and diseases, and limits the provision of ecosystem services essential for long-term sustainability.

Despite their lower economic capacity, family dairy farms play an important role in supporting the resilience of rural areas and preserving traditional agricultural systems. These typologies will serve as a conceptual and empirical basis for the development of mathematical programming models aimed at simulating production, economic, and environmental outcomes, thereby supporting evidence-based policy design and strategic planning in the Croatian dairy sector.

AKNOWLEDGEMENT

The results presented in the paper are an output from the institutional research project Održivi i kružni razvoj mesnog govedarstva u okviru agrarnog sektora

RH (Sustainable and Circular Development of Beef Cattle Production within the Agrarian Sector of the Republic of Croatia) financed from source 581 – Recovery and Resilience Facility (RRF) (NextGenerationEU).

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STRUKTURA ZEMLJIŠTA KAO DETERMINANTA TIPOLOGIJE PRAVNIH SUBJEKATA NA MLIJEČNIM FARMAMA: DOKAZI IZ HRVATSKE

SAŽETAK

Rad predstavlja rezultate klasterske analize provedene na sve 62 pravne mljekarske farme u Hrvatskoj. Cilj je bio grupirati farme u manje homogene skupine sa sličnim karakteristikama prema zadanoj varijabli. Takve skupine farma poslužit će za definiranje tipičnih farma koje će biti temelj za dubinsku procjenu trenutačnoga stanja i daljnji razvoj hrvatskoga mljekarskog sektora. Četiri ključne varijable korištene u klasterskoj analizi odnose se na strukturu ukupne korištene poljoprivredne površine (KPP). Klasterskom analizom identificirano je pet različitih skupina pravnih mljekarskih farma, pri čemu 90% pravnih farma pripada klasteru srednje velikih farma, s jakim razvojnim potencijalom. Pokazalo se da su na pravnim poljoprivrednim gospodarstvima poljoprivredna zemljišta uglavnom oranice, s kukuruzom kao glavnom kulturom. Pokazuju visoko specijaliziranu strukturu usmjerenu gotovo isključivo na ratarske kulture, za razliku od obiteljskih mljekarskih gospodarstva, koja pokazuju veću diverzifikaciju (livade, travnjaci, pašnjaci). Na temelju tih nalaza planira se razvoj modela farma korištenjem matematičkoga programiranja. Analiza se oslanja na podatke iz stvarnoga sektora koje je dostavila Hrvatska agencija za poljoprivredu i hranu (HAPIH), a provedena je korištenjem hijerarhijskih i nehijerarhijskih metoda klasteriranja u softveru **IBM SPSS Statistics*****. Rezultati pružaju čvrstu osnovu za dizajniranje modela na razini farme i doprinose budućim istraživanjima i donošenju politika temeljenih na dokazima u hrvatskome mljekarskom sektoru.***

Ključne riječi: struktura zemljišta, pravne mljekarske farme, klasterska analiza, model farme

(**Received on January 21, 2026; accepted on May 12, 2026** – *Primljeno 21. siječnja 2026.; prihvaćeno 12. svibnja 2026.*)