# ENHANCING DAIRY FARM MANAGEMENT THROUGH PRECISION LIVESTOCK FARMING AND ARTIFICIAL INTELLIGENCE

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***Abstract.*** *The dairy industry faces growing challenges in optimizing productivity, animal welfare, and sustainability. Precision Livestock Farming (PLF) and Artificial Intelligence (AI) are emerging technologies that offer innovative solutions to enhance management practices on dairy farms. This paper explores the integration of PLF and AI in 5 dairy cattle farms from N-E of Romania, covering key areas such as health monitoring, reproductive management, nutrition optimization, and herd performance tracking.*

**Keywords:** Dairy farm management, Precision Livestock Farming, Farm productivity.

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## 1. Introduction

As global demand for dairy products rises, farms are pressured to increase milk production [8]. Growing consumer demand for organic, antibiotic-free, and ethically produced milk puts pressure on farmers to meet these expectations while remaining profitable [1]. Achieving this requires optimizing feed efficiency, cow health, and breeding programs without overburdening animals or the environment.

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Many dairy farms face difficulties finding skilled labour, which affects productivity, particularly with manual milking or farm management tasks [2, 4].

Precision Livestock Farming (PLF), a rapidly evolving field, leverages advanced technologies to monitor and manage livestock with unprecedented precision. By integrating sensors, data analytics, and artificial intelligence (AI), PLF offers the potential to revolutionize dairy farming practices [3, 9]. Although technology like PLF and AI holds promise, many dairy farms still struggle to integrate these technologies due to high costs, lack of technical expertise, or outdated infrastructure [7, 11, 12]. In rural areas where dairy farms are typically located, limited internet connectivity can hinder the adoption of advanced technologies that rely on real-time data transmission, such as AI-driven monitoring systems [6, 10, 13].

Traditional dairy farming often faces challenges related to animal welfare, resource optimization, and market volatility [5, 14, 15]. PLF, in conjunction with AI, offers a promising solution to these challenges. It enables farmers to make informed decisions based on real-time insights by collecting and analysing vast amounts of data on individual animals. For instance, sensors can monitor factors like temperature, humidity, and activity levels, allowing for early detection of health issues and timely interventions [16, 17].

AI algorithms can further enhance the capabilities of PLF by analysing complex patterns within the data. This enables predictive analytics, such as forecasting disease outbreaks or predicting optimal breeding times. Additionally, AI can optimize resource allocation, minimizing waste and improving efficiency in areas like feed distribution and energy consumption.

This paper explores the transformative potential of PLF and AI in enhancing dairy farm management, focusing on areas such as animal health, reproductive efficiency, feed management, and overall farm productivity. Additionally, the study highlights the practical challenges and benefits experienced by dairy farms in integrating these advanced technologies into their daily operations.

## 2. Materials and Methods

The farms are located on the territory of Iasi County, more precisely on the territory of 5 communes: Vlădeni (Farm 1), Holboca (Farm 2), Lunca Pașcani (Farm 3), Prisăcani (Farm 4) and Sirețel (Farm 5), specialising in the rearing of dairy cows.

Farm 1 operates 4,130 hectares of land across several villages, cultivating crops such as wheat, soy, rapeseed, corn, and alfalfa. The dairy farm houses 2,045 Holstein cows, producing over 30,000 litres daily. The farm employs 38 people, including 6 university graduates, 5 veterinarians, and a farm manager who is a

livestock engineer. Employees work in specialized teams (milking, calf care, feed preparation, cleaning, and maintenance). Veterinarians provide 24-hour coverage, and the company offers professional training for all staff levels.

Farm 2, located in Holboca county, focuses on raising Holstein cattle, originating from a nucleus of 420 Holstein Friesian heifers imported from Denmark in 1965. In 1977, this cattle population was recognized as the Romanian Black Spotted breed, known for high milk production and adaptability to Romanian conditions. Currently, the farm houses 890 cattle, including 746 Romanian Black Spotted cattle, 95 Fleckvieh Simmental cattle, and 49 Grey Steppe cattle for genetic conservation. The farm has agricultural land (622 ha), which supplies forage for the animals to sustain the cattle year-round. The farm operates with 92 employees, divided into the productive sector (58 workers), administrative sector (14), and research sector (10), with differentiated work schedules based on activity type. The institution organizes professional qualification courses for employees, both for those with secondary and higher education.


**Fig. 1.** Location of the dairy cattle farms taken into study

Farm 3, manages approximately 3,500 hectares of land, with 1,500 hectares equipped with electric irrigation systems. The farm was modernized in 2007-2008 using European funds, expanding its cattle facilities and acquiring Holstein cows from Germany. In present, the livestock farm includes 1,455 Holstein cattle. The farm employs 42 people, including three with higher education (the manager and 2 veterinarians).

Farm 4 is a family-run dairy farm managed by two brothers. The farm cultivates 680 hectares under lease agreements to provide feed for the cattle. Of the 183

head on the farm analysed, 81 are lactating cows, of the total herd, and 102 head represent the total number of calves. It employs 10 workers, with only the farm administrator holding higher education qualifications. The management does not invest in the professional development of employees.

Farm 5 is a family farm, and focuses on milk production with a herd of 31 cows. The farm cultivates 10 hectares of land under lease agreements to support feed needs. Daily work is organized into a single shift based on a general service norm, with two employees holding secondary education qualifications.

## 3. Results and Discussions

The analysed Farm 1, has a total of 2,045 cattle, 820 are lactating cows (40.1% of the herd), 150 are dry cows, and 1,075 are young female stock (52.57% of the total).

Within the livestock farm there are 3 shelters for lactating cow (1,2,5), 2 milking parlours (3,4), shelter for cows in late gestation (12), calf shelters (7), heifer shelters (6), feed and concentrated feed store (9), silage cells (11), covered straw bale shelter area (9,10), modern manure treatment system (12). The individual calf boxes 0-3 months are constructed of sandwich panels and located between the stalls.


**Fig. 2.** Farm 1 organizational structure

The farm's management technology directly impacts production, reproduction rates, health, longevity, labour productivity, and profitability. The cows are housed in closed barns with individualized resting spaces for 400 cows, equipped with feed alleys, movement zones, and concrete floors. The barns feature artificial lighting, ventilation systems, and automatic grooming. Watering systems are automated, and metal barriers for better access separate the feeding area.

Microclimate conditions like temperature, humidity, ventilation, and floor maintenance heavily influence the cows' health and milk production. Inadequate microclimates can reduce output by up to 10%. The farm uses an automatic manure system. The average cow weighs 600 kg and produces on average 45 litres of milk daily per cow. Feeding is done mechanically with a diet that includes corn silage, brewery grains, alfalfa silage, and various concentrates.

Milking is automated in two parlours BooMatic (2x16 locuri) și DeLaval (2x6 locuri), equipped with cooling tanks and Afimilk Farm Management system. Milk is delivered daily to a processing plant. Artificial insemination is performed by the veterinarians employed in the farm. Reproduction is managed to ensure continuous milk production, with a first insemination at 15 months and calving between 24-25 months. The gestation rest period is about 120 days, and the calving interval is 396-400 days.

As investments in the near future, the farm management aims to build a 50-places rotary milking parlour and two cow shelters to provide more space for the existing herd.

Farm 2 manages a herd of 890 cattle, including Holstein (746), Fleckvieh (95), and the endangered Grey Steppe (49).


**Fig. 3.** Farm 2 organizational structure

Within the livestock farm there are 2 shelters for lactating cows (1,3), between the two shelters there is a milking parlour (2), a shelter for weaned cows/ heifers in advanced gestation (4), individual stalls for calves 0-3 months (5), calf shelters 3-6 months (6), calf shelters 6-12 months (7), shelters for heifers (8), feed and concentrated feed store (12), silage cells (11), covered straw bale area (10), modern manure treatment system (9), summer camp (13), mechanization (14).

The farm is organized by age and physiological state, with lactating cows housed in two closed barns with free-stall shelter. These shelters feature natural and artificial ventilation, automated grooming, and rubber bedding for comfort. Feeding is automated and tailored to physiological needs, with a central feed alley.

Manure is removed by an automatic scraping system and processed for field use. The farm uses advanced reproductive technology, including artificial insemination, and staggered calvings to maintain year-round milk production. The average cow weighs 650 kg and produces on average 28 litres of milk daily per cow, with a diet that includes corn silage, alfalfa, brewery grains, and various concentrates.

Milking is done mechanically in a 16x2 milking fishbone parlour. The process is highly automated, with daily milk production tracked via Farm Management system. Milk is delivered daily to a processing unit. Hygiene and proper milking techniques ensure high-quality milk, with strict sanitation protocols in place.

The Farm 3 has a total herd of 1,455 bovines, of which 405 milking cows, 476 weaned cows, 293 calfs and 281 beef bulls.


**Fig. 4.** Farm 3 organizational structure

Within the livestock farm there are 2 lactating cow shelters (1,3), between the two shelters there is a milking parlour (2), a shelter for weaned cows/heifers in advanced gestation (7), individual stalls for calves 0-3 months (5), calf shelter (4,7), heifer shelter (6), feed and concentrated feed store (11), silage cells (10), covered straw bale area (9), manure separation system (8).

The animals are kept in a closed, free-stall system in modern housing. The shelters are ventilated and illuminated both naturally and artificially, with sprinkler systems to regulate the temperature in summer. The optimum

temperature for dairy cows is between 12-15°C, and deviations can adversely affect production and specific consumption.

The shelters are organized into three zones: rest, movement and forage. Feeding is a key factor in animal productivity and health, and cows are fed a balanced ration that includes compound feed, corn silage, alfalfa hay and other supplements. Manure disposal is mechanized and the farm uses a manure treatment system.

Reproduction is by artificial insemination with semen from international semen suppliers, and the cows have an average weight of 700 kg and produce on average 37 litres of milk per day per cow. Milking is done in a Westfalia milking fishbone parlour with 12 places on each side, and the daily milk yield of about 10,600 litres is delivered to the processing plant.

As investments in the near future, the farm manager is working on a project for the construction of a biogas production plant, he aims to build a shelter for lactating cows and individual calf shelter.

The Farm 4 has a herd of 183 head, of which 81 are lactating cows (44.26%) and 102 are young (55.74%). There are no males reared on the farm.


**Fig. 5.** Farm 4 organizational structure

Within the livestock farm there is 1 shelter for lactating cows (4), a milking parlour/stall for weaned cows (3), a calf/young calf shelter (5,6), feed storage (2), silage cell (7), manure platform (8), office building (1).

The housing is open and the animals are freely maintained with straws for bedding. Ventilation and illumination are both natural and artificial, and water is supplied automatic.

With an average weight of 500 kg, cows produce around 23 litres of milk daily per cow. The feed ratio is administered using a technological trailer.

Reproduction is by artificial insemination, by the veterinarian from the village, and staged calving, ensuring constant milk production throughout the year. The first insemination takes place at 16 months and the first calving at 24 months, with a calving interval of 436 days.

The milking is mechanized, using a DeLaval 4x2, two-row, fishbone milking system. The milk is cooled, stored and delivered to the processing plant.

In the near future, the manager aims to invest in shelters to increase the herd and a manure platform.

The Farm 5 operates 31 dairy Holstein cows. Of these, 27 are lactating cows (87%) and 4 are young cows (13%).

In winter, the cows are kept in tie-stall housing with a capacity of 30 head, natural ventilation and artificial lighting. Manure is disposed of manually and used in the field. The cows are fed alfalfa, hay, silage and grain by hand, and are grazed in summer. Water is administered manually.

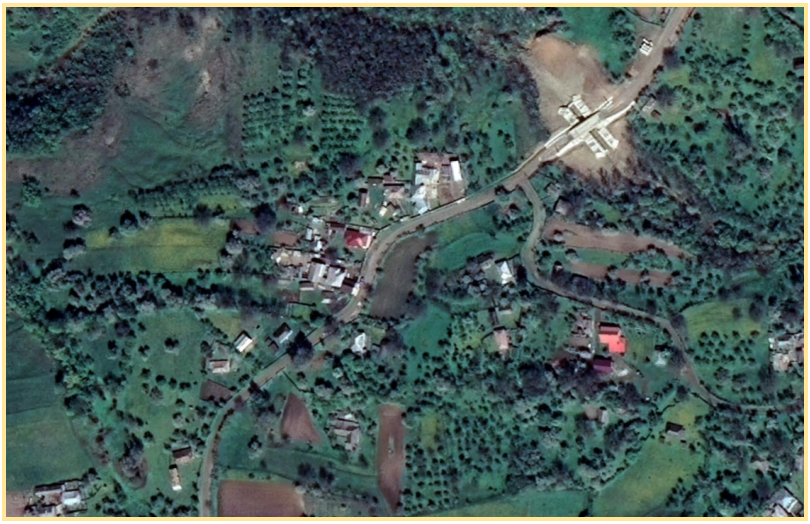

**Fig. 6.** Farm 5 organizational structure

Milking is done in the tie stall with a portable milking machine, one station, one stainless steel drum, with an average of 21 litres of milk per cow daily, and delivered to a processing plant. Artificial inseminations are carried out by the village veterinarian, using 2-3 straws of seminal material per gestation.

In the near future, the farmer aims to invest in shelters to increase the number of cows and the construction of a silage cell.

*Precision livestock farming* is a modern concept that relies on the use of digital technologies and data to manage and monitor each animal or group of animals individually in order to maximize production, optimize health and improve farm profitability.

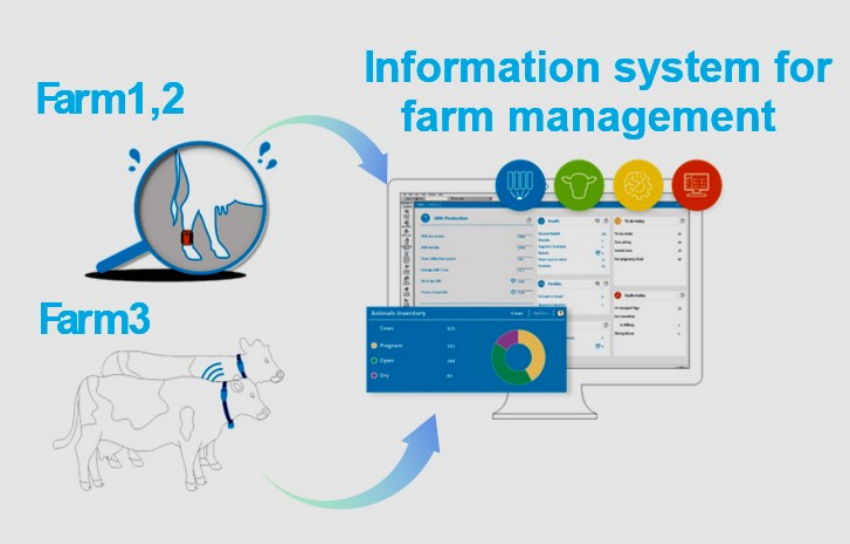


**Fig. 7.** The degree of implementation of precision livestock farming in the dairy farms studied

*a) Digital monitoring of milk production*

Farms 1, 2 and 3 use computerized milking management systems, such as Afimilk, which allows automatic monitoring of milk production for each individual cow. This system detects parameters such as:

- The amount of milk produced: daily, for each cow.

- Milk fat and protein content: essential for monitoring milk quality and animal health.

-Animal behaviour: data can indicate health conditions, heat detection, gestational status and other relevant information.

This data is analysed to adjust feeding, milking and even veterinary treatments, which allows for an individualized approach to each cow.

*b) Digitally assisted reproduction*

Reproductive technology includes artificial insemination, which is planned and monitored using a digital system. Veterinarians employed in farms 1,2 and 3 handle the inseminations, using purchased quality semen, and insemination and gestation data is digitally stored and analysed to improve the success rate. By carefully monitoring age at first insemination, cow weight and breeding cycle, the

farm's reproductive performance can be maximized. In farms 4 and 5, artificial insemination is performed by the veterinarian from the village.

*Process automation*

Farms 1, 2 and 3 use a high degree of automation in all critical stages of livestock management, from feeding the cows to the removal of manure, which contributes to work efficiency and cost reduction.

*a) Automated milking system*

The milking systems in Farms 1, 2 and 3 are fully automated and centralized, which allows for a quick and efficient milking process for a large number of cows. These rooms are equipped with milk cooling tanks to keep it at optimal temperatures before delivery and milk quality detection sensors (fat, protein), which ensure that only the best quality milk is delivered to processing.

In Farm 4 the miking is done automated but there is no informatic system, the quantity of milk being noted in a notebook.

*b) Automatic feeding of cows*

The feeding is done mechanized in Farm 1, 2 and 3 using technological trailers that distribute the fodder automatically and precisely, according to the predetermined rations. These rations are calculated for each group of cows, taking into account physiological condition (pregnant, lactating, etc.), level of milk production, diet composition, including corn silage, beer sorghum, alfalfa, and other nutritionally balanced forages.

*c) Automatic waste disposal system*

Farms 1, 2 and 3 use electric scraper plows for the automatic evacuation of manure from shelters, which are processed in decanting, sterilization and extrusion systems. This technology allows the reuse of manure as sterilized bedding for cows and the use of slurry as fertilizer in agriculture, thus reducing costs and environmental impact.

*Digital maturity*

Farms 1, 2 and 3 have an advanced level of digital maturity, which translates into the use of interconnected technologies and automated systems that allow efficient and precise management of all zootechnical activities.

*a) Centralized management systems*

Afimilk's farm management system not only monitors milking, but collects data on each individual cow, generating daily reports and alerts for technical staff. Thus, farm management can make quick and well-informed decisions regarding

cow health problems (early detection of mastitis, infertility, or other conditions), the need to adjust food rations and efficiency of reproductive processes.

*b) Integration of technologies*

Process automation and data digitization are integrated into a single system that enables remote control and monitoring, which reduces the need for manual intervention and increases the precision of operations. This integration allows the optimal management of resources and the constant monitoring of technical-economic indicators.

*c) Production analysis and optimization*

Data collected through digital systems is used to analyse productivity and optimize all processes on the farm, from feeding to reproduction. This ensures high efficiency and quick response to any problem or fluctuation in production.

Farm 1 is a digitized and automated farm model that uses precision livestock technologies to maximize animal productivity and health. Automation of critical processes such as milking and feeding, together with the use of integrated IT systems, bring a high degree of efficiency and profitability. This advanced level of digital maturity gives the farm a competitive advantage in terms of optimized milk production, efficiency, animal health and overall sustainability. The management is actively planning to invest in modern facilities, including a rotary milking parlor and additional shelters for cows. This indicates a strong commitment to enhancing efficiency and productivity, suggesting that they recognize the value of modern technology and infrastructure in improving farm operations.

Farm 2 uses assisted reproduction systems through artificial insemination, which, although it involves control over the reproductive process, and uses digital technologies to monitor and optimize this process (sensors to monitor health or reproductive cycles). Mechanized milking and manure management systems are used on the farm, and feeding is done with automatic mixer trailers. These technologies indicate a moderate degree of automation in daily operations, and advanced systems for monitoring individual animal parameters (such as devices for monitoring animal health, performance or behaviour) are registered in Afimilk Farm Management system. The farm benefits from modern infrastructures, such as shelters equipped with ventilation and lighting systems, and tries to optimize the processes related to milk production. However, advanced real-time data collection and analysis technologies (e.g. IoT sensors) are not implemented, which places the farm at a moderate level of digital maturity. Although specific investment plans were not detailed (being public entity), the structure and operational approach suggest that ongoing improvements and technology adoption may be a consideration, especially in light of their workforce and production demands. The emphasis on specialized teams may indicate a readiness to

incorporate new practices or technologies that align with their operational framework.

Farm 3 presents a moderate integration of precision technologies, having modern equipment such as shelters with controlled ventilation and lighting, automatic milking systems (Westfalia), and a management system for monitoring milk production. The farm has a project for a biogas plant, which indicates a direction towards sustainability and energy efficiency. However, the digital maturity can be considered moderate. The manager also intend to invest in the construction of a shelter for lactating cows and individual stalls for calves, suggesting commitment to sustainability: This willingness to invest in renewable energy and better housing for livestock suggests a proactive approach to improving both animal welfare and farm sustainability.

Farm 4 has a DeLaval mechanized milking system and uses glass rulers to measure milk, suggesting a lower level of digitization compared to previous farms. Also, the reproductive process, although managed by artificial insemination, does not indicate the use of advanced digital solutions for data management or resource optimization. Digital maturity on this farm is low, implementing only a few basic automation elements. The administrator is planning to invest in shelters and a manure platform to support a larger herd, suggesting a focus on infrastructure. This indicates a recognition of the need to enhance facilities, although it does not explicitly mention PLF technologies. The willingness to invest in infrastructure suggests a potential openness to future technology adoption.

Farm 5 is the least digitized, with simple milking technology and manual feed distribution. Furthermore, the shelter is simple, with no mention of advanced environmental control or animal monitoring systems. The degree of digital maturity is very low, with minimal implementations of modern technologies. The farmer intends to invest in new shelters and a silage cell, reflecting a desire to increase herd size and improve feed management, suggesting an interest in efficiency. This willingness to expand capacity shows an interest in enhancing operational efficiency, which aligns with the principles of PLF.

## Conclusions

(1) Farms 1, 2 and 3 have a high degree of digitization and automation. The use of automated milking systems, IT management of milk production and automatic manure disposal systems reflect an advanced digital maturity. These digital solutions allow continuous and precise monitoring of technical-economic indicators, optimizing the efficiency and profitability of processes.

(2)The degree of implementation of precision livestock farming is limited in farms 4 and 5, and the digital maturity varies between very low and moderate.

Farms are generally equipped with basic equipment, but do not use advanced technology for individual animal monitoring, predictive analytics or integrated digital resource management.

(3)All farms show a willingness to invest in their future, focusing on infrastructure that supports growth and operational efficiency. This willingness reflects a broader trend in agriculture toward modernization and efficiency, positioning these farms to potentially adopt more advanced PLF technologies in the future.

(4)While some farms are more explicitly pursuing advanced technologies (like Farm 1, 2 and 3), others show potential for future PLF investments through infrastructure improvements, revealing varied levels of commitment.

(5)There is an overarching recognition among the farms of the need to adapt to modern agricultural practices, whether through technology, sustainability initiatives, or improved animal welfare standards.

(6)By carefully assessing farm needs, investing in automation, integrating data systems, and leveraging AI for predictive analytics, farmers can transform their operations. Industry stakeholders should support farmers through training, funding, and technological development, ensuring that PLF and AI technologies are accessible and scalable. Adoption of these technologies will not only improve farm management but also contribute to a more sustainable and profitable agricultural sector.

(7)In conclusion, PLF and AI have the potential to significantly enhance dairy farm management by improving animal welfare, increasing productivity, and optimizing resource utilization. By embracing these technologies, dairy farmers can position themselves for long-term success in an increasingly competitive and demanding industry.

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