

# The Dairy Industry In Uruguay: Is The Path Of Intensification Sustainable?

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## Summary

Dairy farming in Uruguay has undergone a profound intensification process in recent decades, doubling its production with half the number of farms. This growth, based on increased stocking rates, individual productivity, and the use of external inputs, has generated economic benefits but also significant environmental pressures. This article analyzes the environmental sustainability of this model, based on an extensive review of national research. It examines critical impacts such as water pollution from nutrient surplus (Nitrogen and Phosphorus), evidenced by the eutrophication of streams and contamination of wells, and soil degradation, with significant organic carbon losses associated with conventional tillage. High-intensification systems, which seek to maximize production, are contrasted with alternative, more pastoral, and lower-cost models that, although achieving lower physical productivity, can achieve similar economic results with less risk and input dependency. The article concludes that while validated tools and technologies exist in the country to mitigate impacts such as integrated effluent management through anaerobic digesters and conservation agriculture (no-till) there is still a long way to go in their widespread adoption. The sustainable future of Uruguayan dairy farming requires a redefinition of efficiency, integrating environmental management as a strategic pillar to align the sector's competitiveness with its long-term resilience.

**Keywords:** dairy farming, environmental sustainability, intensification, effluent management, soil quality, Uruguay.

## Introduction

Dairy farming is a fundamental pillar of the Uruguayan agricultural sector and a relevant player in the international market. In the last three decades, the sector has undergone a profound transformation, managing to double its production while the number of supplying farms was reduced by half (Ortiz et al., 2024). This remarkable growth was not based on an expansion of the national herd, but on a decisive process of intensification: higher animal load per hectare, greater individual productivity, and an increasing use of external technologies and inputs such as fertilizers and concentrated feeds (Durán, 2004; La Manna et al., 2011).

This intensification model has brought undeniable economic benefits, positioning Uruguay as an efficient global competitor. However, it has also raised alarms about its environmental and social costs, generating a crucial debate about its long-term viability. The concentration of production has gone hand in hand with the exclusion of producers, especially smaller-scale ones (Ortiz et al., 2024). From an environmental perspective, intensification concentrates nutrients, puts pressure on natural resources, and raises questions about soil health, water quality, and greenhouse gas (GHG) emissions.

This article aims to analyze, in light of vast local scientific evidence, whether the current path of Uruguayan dairy farming is environmentally sustainable or if there is still much work to be done to align the sector's undeniable productive capacity with responsible management of natural resources.

### The Environmental Pressures of the Intensive Model

Productive intensification, if not managed with an environmental perspective, generates imbalances in agroecosystems. The main areas of concern in Uruguayan dairy systems are nutrient management, soil quality, and greenhouse gas emissions.

### Nutrient Imbalance and Water Pollution

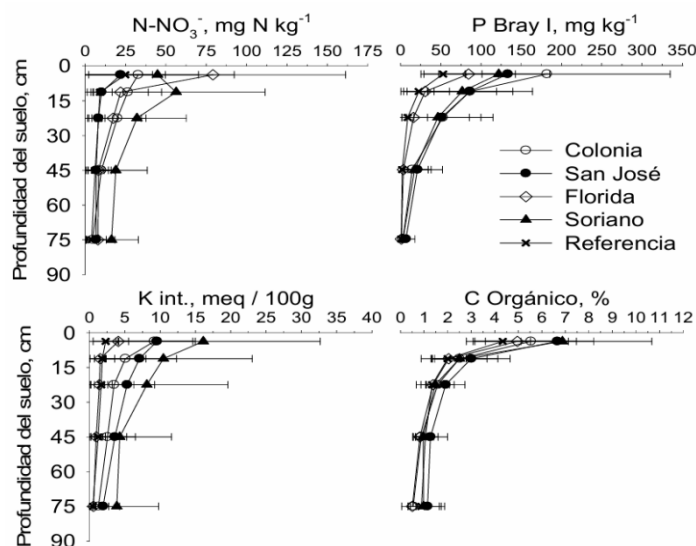
A dairy system is a constant flow of nutrients. They enter the farm through fertilizers, purchased feed, and the biological fixation of legumes, and they exit primarily in the form of milk and meat (La Manna et al., 2011). Intensification, by exponentially increasing the use of external inputs, often leads to a surplus of nutrients, especially Nitrogen (N) and Phosphorus (P) (La Manna et al., 2011). This excess, which the system cannot export in its products, becomes a potential pollutant with the risk of being transferred to water, soil, and air (La Manna et al., 2011).

The risk of pollution materializes through two main pathways:

- **Diffuse Sources:** Losses from erosion and runoff on agricultural and grazing plots (La Manna et al., 2011).
- **Point Sources:** Points of high animal concentration such as milking parlors, holding pens, and, most notably, "sacrifice paddocks" (Ciganda & La Manna, 2011).

These latter areas, used as night confinement areas or feeding yards, have been identified as true "hotspots" of pollution (Ciganda & La Manna, 2011). Studies in the dairy basin have shown a massive accumulation of nutrients at these sites. As observed in Graph 1, the concentrations of Nitrates ( $\text{N-NO}_3^-$ ), Phosphorus (P), and Potassium (K) are extremely high in the top few centimeters of the soil. In the case of nitrate, its high mobility allows it to leach into deeper layers, representing a direct threat to groundwater (Ciganda & La Manna, 2011).

**Graph 1. Nutrient distribution in the soil profile of sacrifice paddocks** (Graph adapted from Ciganda & La Manna, 2011, p. 7)



*The concentration of  $\text{N-NO}_3^-$ , P-Bray, and K is significantly higher in the surface layers (0-30 cm) compared to reference values, decreasing with depth. This highlights the accumulation and the potential for leaching, especially for nitrate.*

The management of liquid effluents (slurry) generated in the milking parlor is another critical challenge. The most widespread practice is the use of lagoon systems; however, in most cases, their design is inadequate, they lack lining, or they have operational failures, turning them into a point source of contaminant infiltration that endangers the groundwater resource (Cisneros Basualdo et al., 2023; Taverna et al., 2004).

The evidence of the impact on water quality is compelling. An exhaustive study in ten micro-watersheds of the Paso Severino reservoir's dairy basin revealed widespread problems (Arocena et al., 2011). The findings included:

- ❖ **Well contamination:** 80% of the analyzed wells showed the presence of coliforms, and nitrate levels exceeded the standard for human consumption (10 mg N/L) in 7 of the 10 watersheds (Arocena et al., 2011). In an extreme case, the proximity of an effluent lagoon to an extraction well raised nitrate concentrations to alarming levels (more than 200 mg/L), as shown in Table 1 (Cisneros Basualdo et al., 2023).
- ❖ **Stream degradation:** One-fifth of the dissolved oxygen measurements in the streams were below the standard for non-urban waters (5 mg/L), with critical values as low as 1 mg/L recorded next to a dairy farm's discharge point (Arocena et al., 2011).
- ❖ **Excess Phosphorus in soils:** Bray-1 Phosphorus levels in sown pastures far exceeded the values associated with maximum productivity (30 ppm), indicating over-fertilization that contributes to the eutrophication of water bodies (Arocena et al., 2011).

**Table 1. Variation of nitrates in water wells in dairy basin.** The case of Dairy Farm 2 at Site 1 shows an instance of severe point source pollution, with values that far exceed the limit for human consumption (50 mg/L). (Table created from data by Cisneros Basualdo et al., 2023, p. 7)

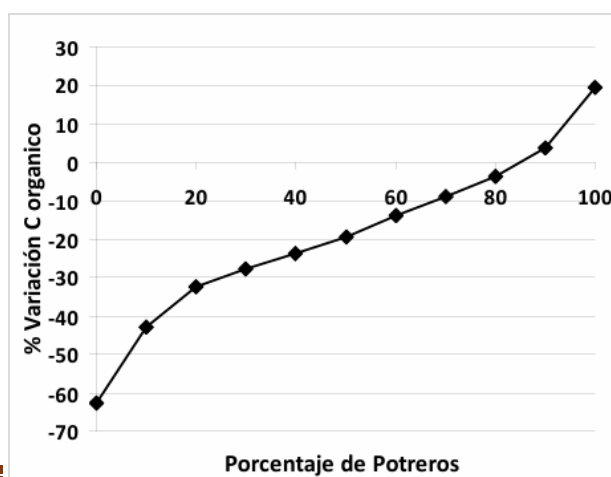
| Dairy Farm            | March 2018<br>(mg/L) | September 2018<br>(mg/L) | February 2019<br>(mg/L) | August 2019<br>(mg/L) |
|-----------------------|----------------------|--------------------------|-------------------------|-----------------------|
| Site 1 - Dairy Farm 2 | 381.9                | 317.6                    | 247.1                   | 220.9                 |
| Site 1 - Ref.         | 45.1                 | 35.2                     | 40.4                    |                       |
| Site 2 - Dairy Farm   | 64.6                 | 51.2                     | 35.4                    | 37.7                  |
| Site 3 - Dairy Farm   | 23.4                 | 29.6                     | 18.2                    | 18.2                  |

### Degradation of Soil Quality

Soil is the main asset of a pastoral system. Its health, often measured by its organic carbon (OC) content, is fundamental for productivity and resilience (Díaz-Rossello & Durán, 2011). Historically, Uruguayan dairy farming was based on forage rotations that involved intensive use of conventional tillage. This practice accelerates the mineralization of organic matter and exposes the soil to erosion, causing a net loss of carbon and nitrogen (Morón et al., 2011).

A comprehensive study covering 86 dairy farms in the country's main basins quantified this degradation. On average, soils under dairy production showed a 20.4% loss of organic carbon and a 16% loss of total nitrogen compared to undisturbed reference soils. As shown in Graph 2, although the average is concerning, the variability is high: almost 30% of the analyzed paddocks recorded organic carbon losses greater than 30%, a severe degradation that negatively compromises the chemical, physical, and biological properties of the soil (Morón et al., 2011).

**Graph 2. Distribution of Organic Carbon variation in dairy paddocks** (Graph adapted from Morón et al., 2011, p. 43)



*The graph shows the percentage variation of Organic Carbon in the production paddocks compared to a reference soil. Nearly 80% of the sites show losses, and 30% have losses greater than 30%.*

Fortunately, this trend is reversible. Research at the Dairy Unit of INIA La Estanzuela has demonstrated that, after an initial period of degradation under conventional tillage (System S1), the adoption of no-till (SD) in forage rotations (Systems R2 and R3), along with intensive management that includes the input of external feed, not only halts the degradation but can also initiate a rapid process of recovery and carbon sequestration in the soil (Díaz-Rossello & Durán, 2011).

**Greenhouse Gas (GHG) Emissions**

Uruguay's GHG emissions profile is atypical: unlike industrialized countries, the agricultural sector is responsible for almost 80% of total emissions (Astigarraga & Picasso, 2011). The main gases are methane (CH<sub>4</sub>), a product of enteric fermentation in ruminants, and nitrous oxide (N<sub>2</sub>O), generated mainly by the excretion of N in the urine of grazing cattle and the use of nitrogen fertilizers (Astigarraga & Picasso, 2011; Ciganda, 2011).

Dairy intensification has a complex relationship with emissions. On one hand, a higher animal load and fiber-rich diets can increase total emissions per hectare. However, intensification can also lead to greater efficiency, meaning a lower amount of emissions per unit of product (e.g., kg of CO<sub>2</sub> equivalent per liter of milk). Strategies such as improving herd efficiency (better genetics, reduction of unproductive animals) are key for mitigation, as they allow for the production of the same amount of milk with fewer animals and, therefore, lower total emissions (Beukes et al., 2009, cited in Astigarraga & Picasso, 2011). The "Carbon Footprint" is becoming a crucial sustainability indicator, not only for its climate impact but also as an increasingly demanded requirement in international markets (Astigarraga & Picasso, 2011).

**The Other Side of the Coin: Is Intensification the Only Way?**

The intensification model, focused on "filling the cow" to express its maximum productive potential (Molinuevo, 2005), has been the driving force of growth. However, this approach has been questioned by producers and researchers who propose that it is possible to design viable systems with lower cost and risk, and therefore, more sustainable (Ortiz et al., 2024).

A recent study in the northwestern littoral of Uruguay compared three groups of dairy farms with different feeding strategies: an intensive group (CON) that fully met nutritional requirements with high levels of concentrates and reserves; and two more pastoral and restrictive groups (OFMA and OFME) that depended more heavily on direct grazing and used fewer external inputs (Ortiz et al., 2024).

The results, summarized in Table 2, are revealing. As expected, the intensive group (CON) achieved significantly higher physical productivity in terms of liters per cow and per hectare. Nevertheless, when analyzing the economic results, the differences blur. The high cost of feed in the CON group consumes a large part of the extra income generated, leading to a final margin per milking cow that is very similar to that of the more extensive systems (Ortiz et al., 2024).

**Table 2. Comparison of physical and economic indicators between dairy systems with different levels of feeding intensification (2-year average)** (Table created from data by Ortiz et al., 2024)

| Indicator                                      | Intensive Group<br>(CON) | Intermediate Group<br>(OFMA) | Extensive Group<br>(OFME) |
|------------------------------------------------|--------------------------|------------------------------|---------------------------|
| <b>Physical Productivity</b>                   |                          |                              |                           |
| <b>Production/Milking Cow<br/>(Liters/day)</b> | 29.2                     | 18.13                        | 11.31                     |
| <b>Liters/dairy ha</b>                         | 9,740                    | 4,130                        | 1,420                     |
| <b>Economic Results (USD)</b>                  |                          |                              |                           |
| <b>Gross Product/cow</b>                       | 8,670                    | 5,550                        | 3,050                     |
| <b>Feeding Cost/Cow</b>                        | 3,710                    | 1,830                        | 1,390                     |

|                                 |       |       |       |
|---------------------------------|-------|-------|-------|
| <b>Feeding Margin/Cow</b>       | 4,970 | 3,720 | 1,660 |
| <b>Total Margin/Milking Cow</b> | 3,310 | 2,390 | 20    |
| <b>Input/Product Ratio</b>      | 0.62  | 0.57  | 1.00  |

This finding is crucial: maximum physical productivity does not always translate into maximum profitability, especially when considering the higher costs and economic and climatic risks that the more intensive systems assume (Ortiz et al., 2024). This validates the logic of many family farmers, whose strategy is not to maximize the result, but to obtain a stable and secure income, avoiding high dependence on external inputs (Figari, 2008, cited in Ortiz et al., 2024).

### Tools for a Sustainable Future: From Diagnosis to Action

The main challenge today is not the lack of knowledge or solutions, but the gap between available technology and its mass adoption. Uruguay has a robust technical and scientific framework to guide the transition towards more sustainable dairy farming.

#### Diagnostic and Evaluation Tools

To manage what is not measured, it is essential to have diagnostic tools. In this regard, the following have been developed and applied in the country:

- ❖ **Sustainability Indicators:** Following methodologies such as the one proposed by MESMIS (Astier et al., 2008), indicator systems have been developed to assess the sustainability of family dairy systems in their social, economic, and agroecological dimensions (García Ferreira & Modernel, 2009; Tommasino et al., 2012). These allow for a rapid and comprehensive diagnosis, identifying critical points such as low income, problems with generational succession, and soil degradation (García Ferreira & Modernel, 2009).
- ❖ **Geographic-Farm Risk Matrix:** Developed by La Manna and Malcuori (La Manna et al., 2011), this matrix is a practical tool for classifying farms according to their pollution potential. It combines geographic risk (soil type, slope, proximity to watercourses) with farm-level risk (number of cows, effluent management, water use). Its application in the Santa Lucía Chico River basin proved effective for prioritizing resources and actions on the highest-risk dairy farms, becoming a key instrument for the design of public policies (La Manna et al., 2011).

#### Technological and Management Solutions

Research has validated a range of concrete solutions to mitigate the impacts:

- ❖ **Effluent Treatment:** Anaerobic digestion using biodigesters is presented as a superior alternative to lagoons. This system not only treats waste safely but also generates valuable byproducts: **biogas** as an energy source (electricity and hot water) and **biofertilizer**, a stabilized organic fertilizer that allows for the safe recycling of nutrients back to the field (Dido et al., 2013). The technical-economic evaluation of these systems has demonstrated their financial viability, with reasonable investment recovery periods, especially when considering tax benefits and energy sales (Dido et al., 2013).
- ❖ **Soil Management: No-till farming (SD)** is established as the practice of choice for forage agriculture. Its implementation in INIA's dairy systems has shown that it is possible to maintain and even increase forage productivity, with operational, economic, and, fundamentally, environmental advantages, such as reduced erosion and the recovery of soil organic carbon (Díaz-Rossello & Durán, 2011).
- ❖ **Productive Efficiency:** As mentioned, improving **herd efficiency** is one of the most effective GHG mitigation strategies. This includes not only genetic improvement but also diet optimization and reproductive management to reduce the number of unproductive animals (Beukes et al., 2009, cited in Astigarraga & Picasso, 2011). The choice of genotypes suited to the production system is also key; animals of intermediate European breeding (F1 crosses) have been shown to be not only more productive under pastoral conditions but also more efficient in using available energy than high-breed animals (Magaña et al., 2009).

### Conclusion



Intensification has been the engine of the impressive growth of Uruguayan dairy farming, but it has left an undeniable environmental footprint on the water, soil, and atmosphere. We are not necessarily on the wrong path, but at a crossroads. Awareness of the problem is growing, research is advancing, and technological and management solutions are available and validated in the national context. However, there is a long way to go for these solutions to become the norm and not the exception.

The future of a competitive, resilient, and accepted dairy industry in the most demanding markets inevitably involves integrating the environmental dimension into decision-making. This implies:

- I. **Promoting Integrated Nutrient Management:** Implementing farm-level plans that balance nutrient inputs and outputs to minimize surpluses and losses to the environment.
- II. **Incentivizing Technological Adoption:** Fostering, through public policies, sustainable financing, technical support, the adoption of efficient effluent treatment systems and conservation agriculture practices like no-till farming.
- III. **Revaluing Efficiency over Maximum Productivity:** Recognizing that the highest profitability does not always come from maximum physical yield, but from the optimization of resource use, opening the door to more diversified and lower-risk systems that can be a viable option, especially for family farming.

Ultimately, the environmental sustainability of Uruguayan dairy farming is not an option, but a necessary condition for its long-term viability. The great challenge is to close the gap between the knowledge generated and the daily practice on farms, transforming environmental management into an intrinsic and profitable part of the dairy business.

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