ESG 5.0 A.I. Risk Assessment & Governance into AgriFood Sector

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Abstract: This paper introduces "ESG 5.0 A.I. Risk Assessment & Governance into AgriFood Sector," a transformative approach to livestock management integrating environmental impact assessment, advanced data analysis, and sustainable farming and agriculture practices for a human-centric A.I. implementation. This approach represents an innovative model aimed at reducing the environmental footprint of livestock operations through A.I. based circular economy approach. This model leverages a Decision Support System (DSS) tailored for real-time monitoring and reporting of Environmental Impact Ratings (EIR), enhancing both productivity and environmental compliance. The DSS employs a multi-layered data collection system, integrating variables on the emissions generated by livestock and the environmental impacts they endure, ultimately supporting a fully sustainable livestock production cycle. Key results include optimized processes for reducing pollutant discharge and minimizing resource waste, driving improved sustainability performance and aligning with European Union Taxonomy (Reg. 2020/852) and Environmental, Social, and Governance (ESG/ESRS) standards. The system not only strengthens animal health management but also bolsters operational efficiency, establishing new benchmarks in circular livestock farming. This model positions itself as a replicable blueprint for scalable and sustainable livestock production that meets both regulatory and societal demands for lower environmental impact based on A.I. human-centric approach.

Summary Statement: ESG5.0 AI Risk Assessment enhances sustainable livestock management via real-time impact ratings, reducing waste and emissions, meeting EU standards, and promoting circular farming practices

Key Words: DSS, Agrifood, Envirnomental Rating, ESG5.0,

Introduction

As the European Union accelerates its transition to a green economy, the environmental footprint of livestock farming remains a critical concern. Addressing this challenge the Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia-Romagna (IZSLER) and the Italian Section of the International Association for Impact Assessment (IAIA Italia) have launched a pioneering collaboration. Their joint effort led to the development of ESG 5.0 — a human-centric, AI-powered environmental governance model centered on a Decision Support System (q-DSS) that enables real-time evaluation and monitoring of livestock environmental impacts. This paper presents the conceptual framework, technical implementation, and early field validation of this model, including results from multiple pig and cattle farms across Northern Italy.

Materials and Methods

At the core of the ESG 5.0 system is its integration with ClassyFarm, a national digital platform developed by the Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia-Romagna (IZSLER) under the coordination of the Italian Ministry of Health. ClassyFarm serves as a comprehensive risk categorization tool for livestock farms, enabling farmers, veterinarians, and competent authorities to assess and manage various aspects of animal husbandry. The platform evaluates factors such as animal health and welfare, antimicrobial usage, biosecurity measures. ClassyFarm operates by collecting and analysing data from farms to classify them into different risk categories. This classification aids in tailoring inspection frequencies and intervention strategies, ensuring that resources are allocated efficiently and that farms maintain high standards of animal health and food safety. The integration of environmental impact assessment into ClassyFarm represents a significant advancement, allowing for a more holistic evaluation of farm operations.

By encompassing environmental considerations, ClassyFarm aligns with broader sustainability goals and regulatory requirements, facilitating a more responsible and informed approach to livestock farming.

The methodological implementation of the new operational evaluation model within ClassyFarm follows a structured five-phase approach, which includes:

1. the sharing of knowledge essential for the implementation of the integrated model for measurement, evaluation, monitoring, and reporting, through the use of methodological and operational tools based on Artificial Intelligence (*phase A1)*. The new environmental module leverages multi-layered data inputs:

    - **Direct environmental pressures generated by farms** (e.g., ammonia and nitrate emissions);
    - **Environmental pressures experienced by farms** (e.g. air quality degradation, groundwater vulnerability, climate conditions, cumulative environmental impacts);
    - **Operational characteristics** (e.g., housing type, livestock density, wastewater management);
    - **Supply chain externalities** (e.g., feed production, waste processing, logistics).

    Figure 1 illustrates the operational workflow encompassing the entire supply chain process associated with the livestock production unit.

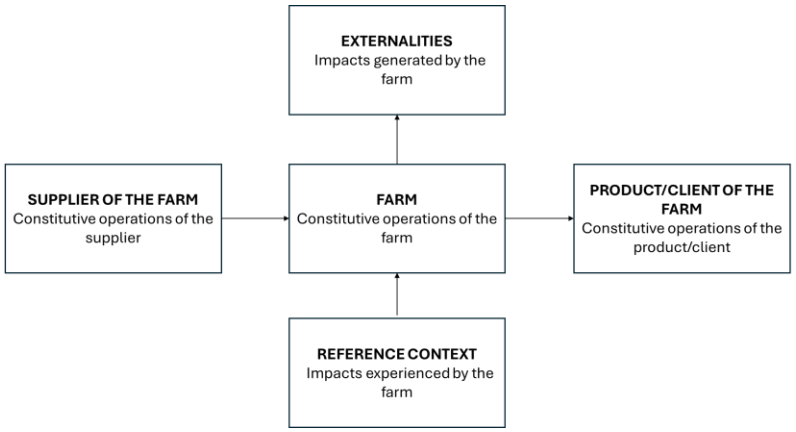


Figure 1: Methodological reference framework for the entire livestock supply chain.

These elements are processed through a multi-criteria framework aligned with:

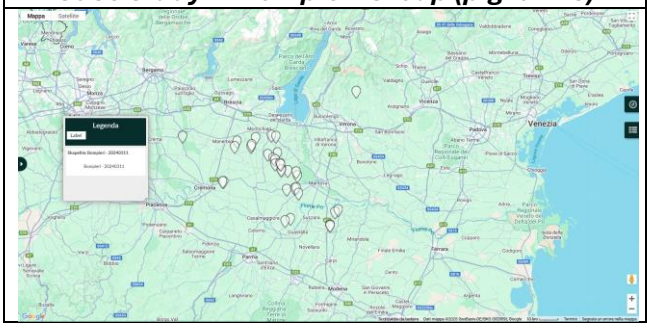
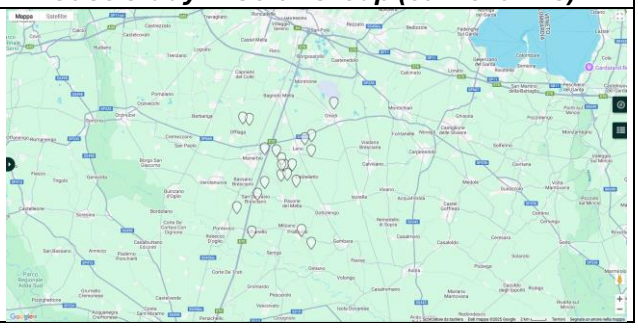
- EU Taxonomy for sustainable activities (Reg. 2020/852);
- DNSH ("Do No Significant Harm") principles;
- European Sustainability Reporting Standards (ESRS, Reg. 2023/2772).

2. the application of the integrated characterization model to a case study (*phase A2*);
3. the sharing and validation of the model, along with the identification of strategies for implementing measures aimed at improving impact performance (*phase A3*);
4. the technological integration of the environmental measurement and evaluation system within the ClassyFarm Platform (*phase A4*);
5. the deployment of the application functionalities provided by the model in the ClassyFarm system, and the initiation of the operational management phase (*phase A5*).

Results and Discussion

The pilot deployment of the q-DSS system was conducted across multiple livestock farms in Northern Italy: the pig farms (*Bompieri group*) and cattle farms (*Solat group*) are distributed across various municipalities in the Lombardy and Emilia-Romagna regions - areas characterized by intensive livestock production and high population density. Several farms are situated in zones identified as environmentally sensitive, such as:

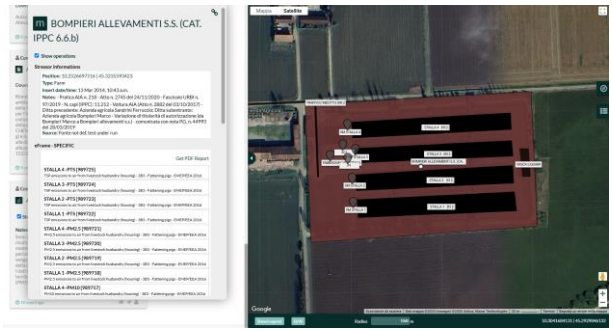
- **Nitrate Vulnerable Zones (NVZs):** Areas already under pressure from agricultural pollution where manure management practices have a heightened environmental impact.
- **Proximity to watercourses or protected natural areas**, increasing the environmental risk associated with runoff and emissions.
- **Groundwater-dependent areas**, where over-extraction or contamination poses threats to drinking water reserves.

Case study 1: Bompieri Group (pig farms)	***Case study 2: Solat Group (cattle farms)***
	

Among the pilot applications of the q-DSS system, a representative case study was conducted on a fattening pig farm located in the municipality of Leno (Brescia province). This farm exemplifies an intensive pig production system and was selected for its structural characteristics and potential environmental interactions. The farm comprises four housing units, all adopting a multi-box housing

system with an external defecation corridor. The floors are partially slatted, with external slatted corridors that facilitate the collection of manure and wastewater.

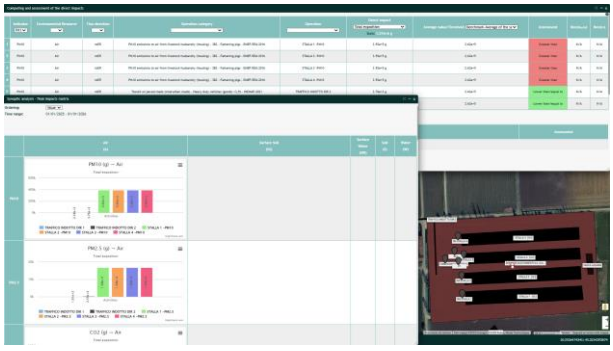
Environmental constituent operations refer to the structural and functional elements of the farm that directly influence environmental performance



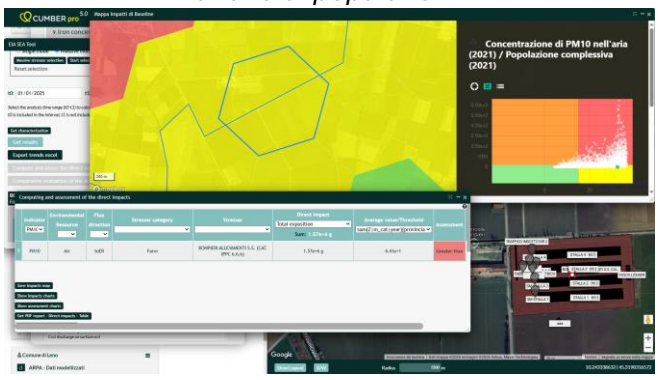
The reference environmental and territorial context in which the farm operates (A 1500-meter radius buffer zone centered on the farm under study)

Using the q-DSS model, the farm's operations were analysed to evaluate both the generated emissions and the environmental pressures experienced due to its location.

Generated emissions from the farm's operations – focus on PM10

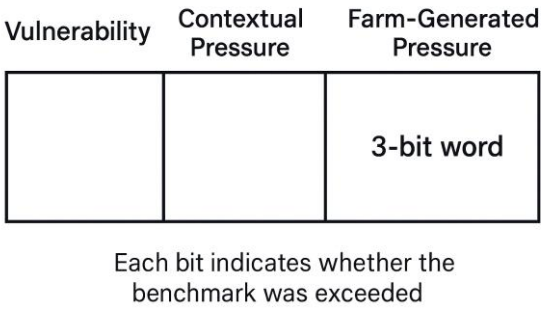


Materiality level of the impacts from the farm's reference environmental context- focus on PM10 and total population

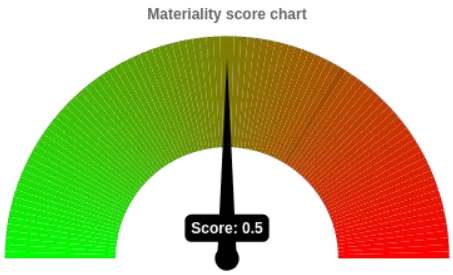


The integration of generated emissions and site-specific environmental pressures enabled the first attempt at assigning an Environmental Impact Rating (EIR) for the farm. This rating was obtained through a normalized sum of impact contributions, each represented as a 3-bit word, where each bit indicates whether a specific benchmark has been exceeded. The bits are ordered by descending significance: vulnerability, contextual pressure, and farm-generated pressure.

Visual diagram representing the 3-bit logic structure

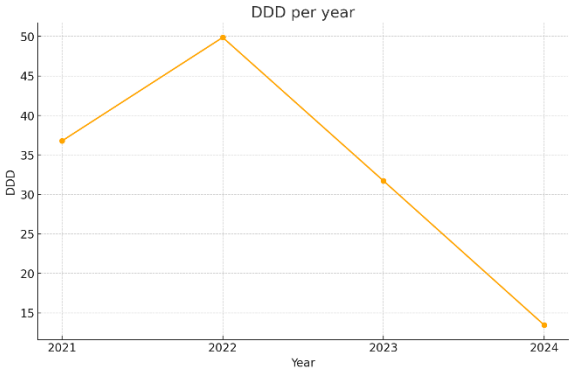


First attempt at assigning an Environmental Impact Rating (EIR) for the farm

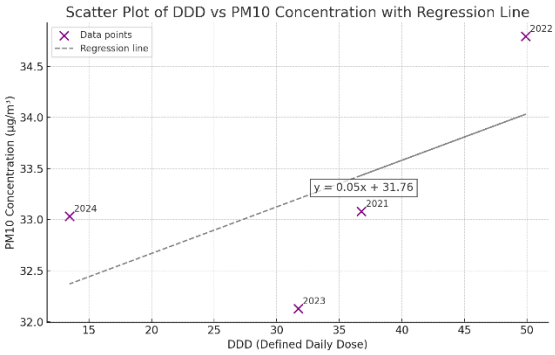


As a preliminary step toward identifying impact mitigation strategies, correlation analysis was carried out between the site-specific environmental pressures (focused on PM10) and antimicrobial usage data, expressed in Defined Daily Doses (DDD), covering the period from 2021 to 2024.

DDD per year - DDD (Defined Daily Dose) for the farm



Correlation analysis



The chart shows the trend of veterinary drug usage (DDD) and average PM10 concentration over the years 2021 to 2024. The Pearson correlation coefficient between DDD and PM10 is approximately 0.62, indicating a moderate positive correlation. This suggests that years with higher PM10 levels also tend to have DDD higher values. While this correlation could hint at a possible link between intensive livestock management and air quality, the dataset is limited to four years. Therefore, further investigation with a larger data set would be necessary to draw robust conclusions.

Conclusion

The ESG 5.0 model represents a pioneering step in integrating Artificial Intelligence into environmental risk assessment and governance within the livestock sector. Through the implementation of the q-DSS system and its integration into the national ClassyFarm platform, this model will offer a replicable and

scalable framework for measuring and reporting the environmental impacts of livestock farming, aligned with EU Taxonomy, DNSH principles, and ESRS standards.

The pilot case studies demonstrate the system's ability to contextualize environmental performance using both emission data and territorial vulnerability, resulting in the first attempt to compute an Environmental Impact Rating (EIR) for livestock farms. The adoption of a structured 3-bit model allows for a compact, hierarchical representation of impact drivers, facilitating transparent benchmarking and targeted mitigation.

Furthermore, the preliminary correlation analysis between PM10 levels and antimicrobial use (DDD) suggests a potential link between environmental pressure and animal health management practices. While the data set is limited, these findings support the value of integrated, multidimensional monitoring tools in driving sustainability.

Overall, ESG 5.0 provides a human-centric digital governance approach that strengthens decision-making capacity at both the farm and policy levels. It sets a foundation for a new generation of permitting tools capable of supporting circular farming, environmental compliance, and strategic alignment with the green transition agenda.

Reference

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