2020 IEEE *26th International Symposium for Design and Technology in Electronic Packaging (**SIITME**)*

Decision support platform for intelligent and sustainable farming

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***Abstract* — The growing demand for animal products led to an increase of the number and size of animal farms across the world. In this context, the livestock farming industry faces the challenge of integrating high complexity processes, while ensuring to meet sustainability standards. Therefore, decision support systems in the livestock sector must be established to help farmers assess the impact of different strategies before putting them into practice. In this paper, we present a monitoring and management platform that allows farmers to optimize their activities, to manage resources, to reduce costs and to minimize the environmental footprint. The FarmSustainaBL platform follows a farm-level approach for modelling and simulation of specific activities to assist decision makers and farmers in the decisional process, by providing insights into their managerial practices.**

Keywords — sustainable farming, GHG emissions, livestock monitoring platform.

I. Introduction

Most individual farms have low economic power and limited opening to the market, both in terms of inputs and outputs required. These farms are characterized by a very diverse production structure, as well as by insufficient and inadequate technical equipment, which hinders productivity. Given the context of the current economic downturn and limited access to capital, small market-oriented farms need to be supported by innovation actions, in order to achieve goals such as increasing the number and size of farms, more efficient livestock management and reduction of greenhouse gas (GHG) emissions [1]. For this purpose, the development of livestock monitoring, and management platforms can enable farmers to optimize their activities, to minimize costs and to reduce the environmental footprint. These decision support systems based on modelling and simulation help stakeholders in the livestock sector to take appropriate actions towards more productive and sustainable farming [2].

This paper presents a monitoring and management platform that assists farmers in the decisional process, by facilitating the optimization of specific activities and better resource management, to reduce costs and to minimize the environmental footprint. The following sections of the article will approach the subsequent matters: Section II examines the current context and investigates related work, Section III details the use cases, Section IV showcases how the system requirements are established and section V describes the system design. Finally, Section VI presents the conclusions and future work.

II. Agriculture and GHG emissions

The livestock sector is the main source of CH4 emissions in agriculture, as a cause of both enteric fermentation and manure management.

A. Sources of greenhouse gas emissions on livestock farms

The Agriculture sector contributed by adding 16.85% to total GHG emissions in 2017, reaching the equivalent of 19231.76 kt CO2. In the context of GHG emissions in the agricultural sector, CH4 emissions make the largest contribution, followed by N2O emissions. Between 1989 and 2017, GHG emissions from the agriculture sector in Romania decreased by 50.86%. The number of animals decreased during this period, regardless of species and type of operation. Cattle raised for beef, milk or traction power are the animal species responsible for the most emissions, accounting for about 65% of the emissions of the livestock sector. With reference to farming activities, the production (including processing) of feed and enteric fermentation from ruminants are the two main sources of emissions, accounting for 45% and 39% of total emissions. The storage and processing of manure accounts for 10% of all emissions. Approximately 44% of animal emissions are represented by methane (CH4). The remaining part is almost evenly divided between nitrous oxide (N2O, 29%) and carbon dioxide (CO2, 27%). This means that animal supply chains emit: 5% of anthropogenic CO2 emissions, 44% of anthropogenic CH4 emissions and 53% of anthropogenic N2O emissions [4].

B. GHG estimation methodologies

The internationally recognized methodology for estimating GHG emissions from livestock farming is the one proposed by the Intergovernmental Panel on Climate Change (IPCC) and is the method used by the countries included in Annex I to the United Nations Framework Convention on Climate Change (UNFCCC) for international reporting of these emissions. The methodology is structured on three levels, depending on complexity and accuracy [5]. The basic characterization for level 1 is probably sufficient for most animal species in most countries. For this approach, it is good practice collecting the following data: Species and categories of animals, annual population, feed intake, etc.

III. Precision livestock farming

In recent years, the growing demand for animal products led to an increase of the number and size of animal farms across the world. Farmers are faced with a multitude of challenges in order to properly manage their business, as they have to consider increasingly complex factors within their decisions, such as: more diverse and larger numbers of animals to manage, more demanding production requirements, complex business models to choose from, environmental restrictions, etc. Thus, the transition from conventional agricultural practices to more technology-based approaches is mandatory. In this regard, the newest advancements in technology will enable the development of Precision Livestock Farming (PLF) [6]. This concept refers to tools such as real-time and continuous livestock monitoring, farm-related data collection, data analysis, predictions and incident reporting. Using sensors that measure biosignals, PLF can also be used to monitor animal welfare, their overall condition (physical and mental), changes in behavior. Other common sensors employed in PLF collect data parameters for different purposes:

- stable environment conditions: (temperature, humidity, light, gas concentrations)
- animal motions: (gait, speed, position, weight, temperature, sounds)
- animal feed: (composition, flow, weight)

Aside from monitoring, Precision Livestock Farming is useful for more complex tasks such as: modeling, simulation and decision support using machine learning models. Commonly, the main elements of PLF include: continuous or real-time processing of sensor data, data integration and storage, data analysis and modeling, event detection and signaling [7].

A. The use of AI and Blockchain for precision livestock farming

In recent years, since the complexity of the systems involving animals has grown, their monitoring became more difficult and the gathered data increasingly heterogeneous. Therefore, the need for decision support is essential for decision makers, who are constantly faced with making crucial management decisions to meet their objectives: improving animal welfare and reducing GHG emissions.

The incorporation of artificial intelligence algorithms (machine learning and / or deep learning) in decision support for PLF helps stakeholders to achieve several objectives, due to the characteristic usually attached to intelligence - the ability to learn from the environment. Artificial Intelligence in livestock farms helps in accumulation and analyzing data for accurate prediction of consumer behavior (i.e. buying patterns, leading trends). In this way, with the necessary investments, farmers will be able to automate processes, reduce high costs and get a better quality of livestock products, like milk. Taking into consideration that AI and ML are becoming more available and are expected to advance the automation of most of the farm processes and, at the same time, produce information based on the farm's operational history. AI allows producers to interpret data collected by sensors and hardware technologies to provide solutions by mimicking human decision-making - potentially transforming how a smart farm operates [8].

Blockchain is used in many applications of precision agriculture. The technology plays a significant role, the one of replacing the basic methods of storing, sorting and also sharing the agricultural data into a more immutable, reliable, transparent and decentralized way. Blockchain technology is a digital register in which the details of transactions made between users are stored. A blockchain can be considered a dynamic list of records that can only grow, because changes such as deleting or changing previous records are not possible [9]. In the context of precision farming, blockchain technology mixed with the Internet of Things will make the transitions from only smart farms to the internet of intelligent farms and also will increase the control in supply-chains networks. This combination will result in the autonomy and intelligence in managing precision farming in an efficient and optimized way [10]. Blockchain represents the source of truth about the state of farms and contracts in agriculture; here, the collection of this information is very costly. It facilitates the use of data-driven technologies to make farming smarter - reliable data of farming processes are essential for developing data-driving facilities and insurance solutions, facts that make farming smarter and less vulnerable [11].

B. Precision livestock farming Platforms. Related work

The widespread adoption of the Precision Farming concept within the livestock farming industry has the potential to bring more efficiency and real-time capabilities for the supply chain management, to significantly increase productivity, to strengthen the marketing strategies and to reduce the environmental impact of the farming sector. This concept has been investigated within several scientific studies and has been successfully applied in various use cases, presented in the following paragraphs.

Cisco proposes a framework for the implementation of a precision farming platform based on artificial intelligence software which lowers the data volume that needs to be sent. The platform relies on measuring animal movements by processing collar information. With the approach mentioned above, operating lifetime is more than five years without the need for a battery change. Longer battery life is also due to the LoRa protocol instead of LPWAN technologies. By using a simple measurement of the acceleration on the neck, the platform can identify the animal's behavior. An experiment built on a GPS-based collar for cattle management was performed in sub-Saharan Africa countries. The demonstration shows good tracking skills of the used software and registered low-cost solutions compared to other existing PLF platforms [12].

The e-Pasto platform [13] can deal with the most common challenges of the PLF platforms, such as adequacy of the communication protocols and energy usage. A study presents an accelerometer-based solution that improves the energy efficiency of embedded geolocation devices, allowing at the same time an essential animal activity identification. The Machine Learning algorithm used for the suggested solution is based on the moving average method and due to its accuracy, it can successfully identify different animal movements.

A study conducted in 2017 in France [14] explored the viability of the architecture of a farming platform and its performances. The innovative result of the experiment was the validation of a virtual fencing solution that helped farmers to decide and draw the size and shape of the virtual fences with the point-in-polygon geometric computation principle. The scope of the virtual fence is to warn the farmer that the animal went out of the limits and to offer decision support to solve the problem.

One study published in 2020 proposes a blockchain-based framework for managing the agricultural supply chain [15]. The authors propose a framework that integrates IoT-based solutions to enable food traceability and transparency. Another study [16] presented in 2018 in China proposes a public blockchain of the agricultural supply chain system to demonstrate that the advantages of blockchain such as confidentiality, openness and security of information can greatly strengthen the credibility of upcoming service platforms in the field and the efficiency of the system as a whole. In 2019, the article [17] examined whether blockchain is a suitable solution for supply chain management and concluded that it can lead to lower error rates at various stages of the supply chain and improve customer support. For the study, weight sensors were used to measure product weights to enable tracking the transaction between the trader and the customer, which is visible to both parties involved. Another study carried out in 2018 analyzed the implementation of ICT solutions, systems and functions (such as Cloud/Fog and IoT) to make the food supply chain possible [18] and demonstrated that intelligent technology solutions will increase transparency, information flow and management capacity to enable farmers to better interact with other stakeholders within the supply chain. The study proposes a new business model regarding on-demand foods based on the new values of Quality of Experience (QoE) Food Metrics, eliminating the gap between subjective experience and objective indicators based on quality standards.

IV. USE CASE DESCRIPTION

To demonstrate the functionalities of the decision support capabilities of the PLF platform, certain aspects of the use cases have be taken into account: the main objectives of the platform (seen through the eyes of users), the business model (actors involved), the main functional characteristics, the functional components and the requirements associated with the use case (from the main users of the system).

The FarmSustainaBl platform will be tested in two case studies that were selected considering the amount of greenhouse gas (GHG) emissions produced and the processes from which they result. As such, one of the case studies aims to manage GHG emissions from manure, while the other case study addresses the management of CH4 emissions from enteric fermentation. The approach to GHG emissions at farm level (Figure 1) includes direct emissions (from enteric fermentation and manure), indirect emissions (associated with electricity consumption and fuel used in internal processes, e.g. for agricultural machinery) and emissions of indirect greenhouse pollutants (PMx, NH_3, etc.).

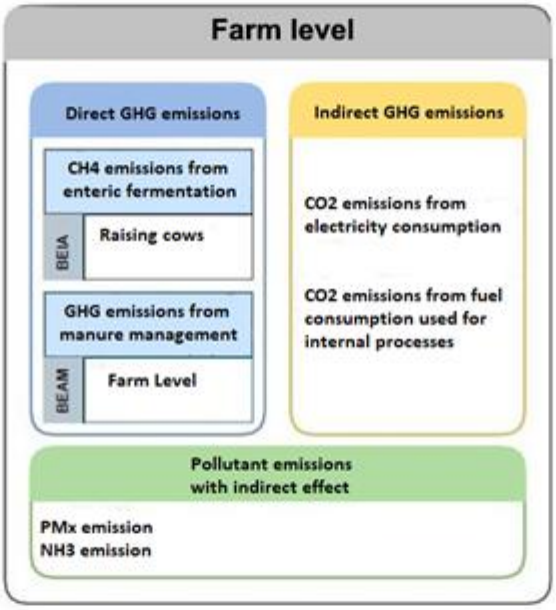

Figure 1. Types of emissions included in the FarmSustainaBL platform.

The developed platform will collect and analyze all these data to provide recommendations to the livestock farming stakeholders (such as farmers, consultants etc.) in order to take management and operational decisions for reducing GHG emissions.

V. DEFINITION OF SYSTEM REQUIREMENTS

The process of defining the system requirements for the proposed solution must consider different sets of information:

- Requirements of stakeholder that can refer to: primary users (requirements from use cases), operator/beneficiaries (efficiency requirements, management and control possibilities, operation, commercial requirements, etc.) or third parties (secondary users) - (requirements arising from use cases).
- Constraints: pre-defined initial design data (eg use of only certain technologies, maximum system size, cost, etc.).
- Conditions: end-user features, availability of resources, including business / commercial. Changing these conditions can influence the behavior and results of the system.
- Dependencies: functional or performance elements of other systems, on which the correct functioning of the system to be performed depends (if the latter has external interactions).

  After closely considering the information presented above, the system requirements will be established using the general sequence of steps presented in Figure 2.

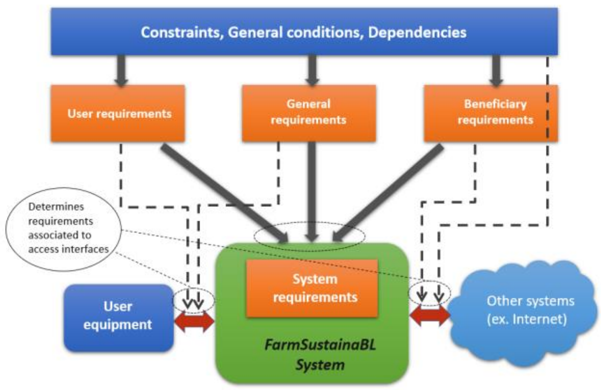

Figure 2. Illustration of the methodology of analysis and collection of system requirements.

VI. SYSTEM DESIGN

The concept of the FarmSustainaBl platform consists of three main components that will be developed on existing farm infrastructure, as detailed below.

A wireless sensor network that will measure specific parameters such as environmental, animal and feed data. The sensors will transmit information via a wireless technology (LoRaWAN) to a sensor measurement aggregator which will communicate with the FarmsustainaBl Cloud.

The FarmSustainaBl Cloud which will enable the realization of the GHG reduction as well as the traceability of the feed and livestock management. It consists of the following components:

- the gateway - the main entry point to the FarmSustainaBl Cloud, responsible for receiving processed and indexed measured sensor data and for sending control and configuration data to the sensor farm environment.
- the data analytics module is responsible for providing meaningful insight on livestock and farm data by performing analytics and business intelligence.
- the blockchain component that will enable smart contracts for automatically offering the best prices for low-GHG emission farm produce.
- the decision support system that will use collected data and data analytics to build models and simulate the farm performance according to different metrics with the purpose of testing various scenarios to determine optimal configurations of farm systems.

The web-based FarmSustainaBl platform that will be a one-stop shop for the platform services such as: business decisions related to low-GHG emission livestock farming, smart contract management, GHG-emission management and tracing, etc.

VII. CONCLUSIONS

Through this paper we highlighted the current technological possibilities of advancing an innovative decision support platform that can optimize operation for livestock farmers by providing valuable information for decision making. The research work performed within the FarmSustainaBl project shows an indisputable need for solutions that can help the livestock farming industry face the challenges of integrating increasingly higher complexity processes, while ensuring to meet sustainability standards. Aside from the decision support system, within this paper, we have presented the process of defining the system requirements of the solution and the main components that will be developed during the project.

The future work will involve the integration of the presented system on existing farm infrastructure and the test field validation of the decision support platform, through the use case demonstrators planned to take place in a cattle farm in Romania.

ACKNOWLEDGMENT

The work presented in this paper has been funded by MCI and European Union, under ERANET-ERAGAS-ICT-AGRI3 program, through FarmSustainaBL project (contract no. 119/2019). We would like to express our gratitude to Tel-MONAER project (subsidiary contract no. 1223/22.01.2018, from NETIO Project ID: P 40270, MySMIS CODE: 105976) and WINS@HI project (PN-III-P3-3.5-EUK-2017-02-0038) for the work presented in this paper.

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