Enhancing precision livestock management with IoT: Insights from the WELLNESS project*

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Abstract

The utilization of Information and Communication Technologies (ICT) in livestock management has revolutionized traditional farming practices, enabling farmers to operate with precision and efficiency. ICT technologies facilitate real-time monitoring of animal health, behavior, and environmental conditions supporting productivity and sustainable farming practices. The objective of WELLNESS Project is to use ICT technologies in small ruminant systems located in Bourinos mountain region. GPS trackers were fitted on individual sheep and goats that were randomly selected from three flocks raised semi-intensively in order to monitor movement patterns and behaviour. In two farms portable meteorological stations were mounted in the outside walls of the barn to collect weather data. One station used LoRaWAN technology for efficient, long-range data transmission. This approach aims to allow for the correlation of environmental factors with livestock behavior, enabling the development of wellbeing indices and the assessment of milk quality specific to the Bourinos mountain region.

Keywords

Internet of Things (IoT), precision livestock, animal welfare, sustainable agriculture, smart collars

1. Introduction

The integration of advanced information and communication technologies (ICT) into various sectors is revolutionizing traditional practices, enabling more precise and efficient operations. In agriculture, these technologies, including the Internet of Things (IoT), have the potential to transform livestock management, enhancing productivity, sustainability, and product quality [1]. The adoption of IoT solutions in farming can provide real-time data, promote the sustainable use of resources, and facilitate evidence-based decision-making [2]. This integration allows for the systematic monitoring and evaluation of critical parameters that can be used to assess animal welfare, leading to a reduction in overall costs and human errors. Consequently, it enables rational management of the entire production and processing cycle of milk, from production to market entry. Thus, an efficient and specialized decision support system (DSS) for livestock management and milk production is essential.

To this end, the WELLNESS project focuses on the development of a comprehensive system for

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recording productive parameters and holistic management of goat and sheep farms in milk-producing regions. By implementing a parametrized low power wide area network (LPWAN) and IoT end-devices, WELLNESS provides real-time measurements from livestock environments, enabling systematic monitoring and evaluation of critical parameters to assess animal welfare.

The WELLNESS system offers several distinct advantages over existing solutions: it monitors and records data on animals, farming operations, and environmental conditions on the farm using IoT sensors; it alerts producers to potential health issues; and it provides the ability to read, process, and display detailed information at the individual animal level. Animal health can be efficiently monitored and tracked using smart collars. Furthermore, by recognizing potential problems in near real-time, prioritizing them, and proposing appropriate solutions, the system helps in better organizing and restructuring the milk production process in goat and sheep farming enterprises. This ultimately ensures high-quality milk production and supports the economic viability of agro-livestock enterprises.

Additionally, the project aims to support local cheese dairies by improving the quality characteristics of the milk produced, thereby enhancing the value-added products derived from dairy processing. The main concept of the project is graphically illustrated in Fig. 1.

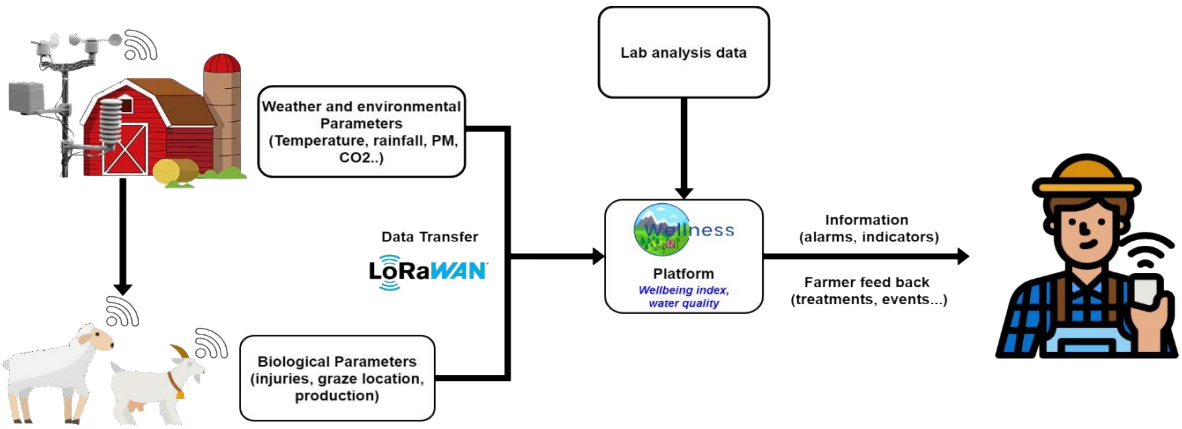

Figure 1: WELLNESS project main concept

2. Pilot description

The pilot case is implemented in two cheese dairies and three selected dairy farms near the Bourinos mountain in Kozani, Western Macedonia, Greece as shown in Fig. 2, offering a modern Precision Livestock Monitoring and Management System based on IoT. This initiative aims to ultimately improve the organization and efficiency of milk production in goat and sheep farming enterprises.

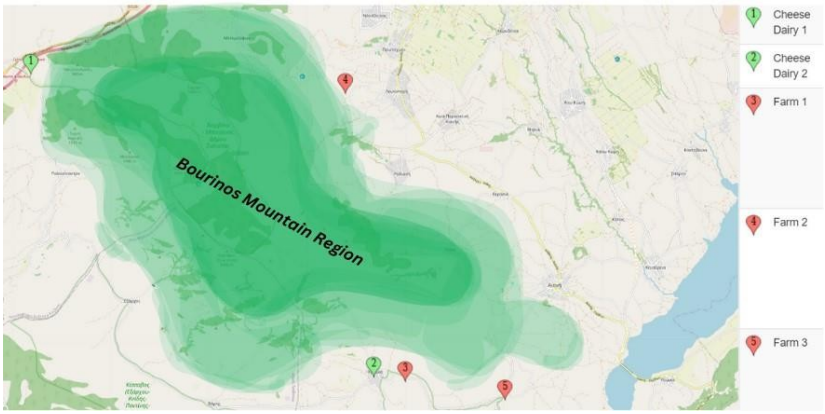

Figure 2: WELLNESS pilot map

2.1. Data collection

In the WELLNESS Project, our approach to enhance precision livestock management leveraged the power of the Internet of Things (IoT) to gather comprehensive data from two semi – intensive dairy goats farm and one intensive dairy sheep farm. We employed GPS trackers to monitor the movement patterns of sheep and goats, providing valuable insights into their behavior and grazing habits. Additionally, two of the farms were equipped with meteorological stations to collect weather-related data, with one station utilizing LoRaWAN technology for efficient, long-range data transmission. This multifaceted data collection strategy enabled us to integrate environmental and coordinate data to determine wellbeing indices and milk quality specific to the Bourinos mountain region, paving the way for more informed and precise livestock management practices.

2.1.1. Meteorological stations

Two agrometeorological stations were deployed in the experimental area to collect environmental and weather conditions. These stations measure a variety of parameters including temperature, humidity, wind speed and direction, barometric pressure, precipitation, solar radiation, particulate matter (PM1, PM2.5, PM10), and carbon dioxide (CO2) levels. Detailed information regarding the measurements of each station is presented in Table 1. The data collected by these stations provide critical insights into the local climate and environmental conditions, which are essential for optimizing livestock management. In Fig. 3 the meteorological stations in pilot farms are shown.

Table 1
Meteorological Stations Measurements Parameters

Measurement	Station 1	Station 2
Temperature	x	x
Humidity	x	x
Precipitation	x	x
Pressure	x	x
Wind Speed	x	x
Wind Direction	x	x
Solar Radiation	x	-
PM1	x	x
PM2.5	x	x
PM10	x	x
CO_2	x	-

The significance of the data collected by these meteorological stations is immense. Precise measurements of temperature, humidity, and wind conditions allow for the assessment of the comfort and potential health risks for cattle, as extreme weather conditions can cause stress and illness [3]. The quality of air is determined by monitoring the amounts of particulate matter and CO2. Addressing heat stress in regions with elevated temperatures is particularly contingent upon sun radiation data. Observations of precipitation and barometric pressure aid in predicting weather patterns, can facilitate enhanced planning and management of agricultural operations. Overall, the comprehensive environmental data provided from these open-data sources assists farmers in making informed decisions, therefore improving animal welfare, productivity, and the long-term viability of livestock production.

Figure 3: Meteorological stations in pilot farms

2.1.2. Smart Collars

The WELLNESS project uses GPS tracking technology integrated into animal collars to monitor the movement and behavior of animals. This system incorporates the Arduino MKR series microcontroller, renowned for its efficient energy use [4] and advanced computational powers, making it well-suited for remote IoT applications. The essential elements are the GPS NEO module, an SD shield, a DHT11 temperature and humidity sensor, a battery unit, and LoRaWAN technology for transmitting data.

The GPS NEO module obtains real-time geolocation data by establishing communication with GPS satellites. The DHT11 sensor quantifies the surrounding temperature and humidity, enabling us to establish a connection between environmental conditions and animal actions. The SD shield guarantees uninterrupted data collection by recording GPS coordinates in addition to temperature and humidity measurements, even in situations when immediate transmission is not feasible. Moreover, a printed circuit board (PCB) has been designed for collars (Fig. 4), which will help in reducing both the size and weight of the device. This custom PCB integration is crucial for ensuring the device remains comfortable for the animals while maintaining all necessary functionalities. The smart collar is equipped with a lithium polymer (Li-Po) battery, selected for its exceptional energy density and lightweight characteristics, enabling extended field operation without imposing any additional weight on the animals.

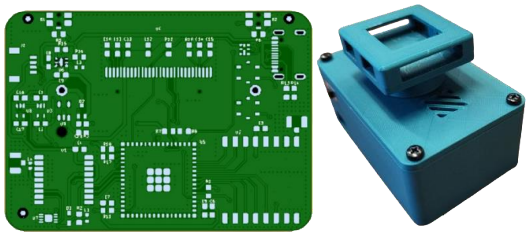

Figure 4: WELLNESS PCB Smart Collar

3. Animal wellbeing indices

Minimizing the factors that cause stress on farms leads to improved animal welfare and productivity. Monitoring schemes should incorporate indicators that possess validity, reliability, and sensitivity [5]. Furthermore, it is crucial that they are both practically viable and applicable in real farming conditions. A series of environmental indices has been selected to assess the overall animal wellbeing in the selected farms [6]. These stressors include thermal stress and air quality measured by calculating the Air Quality Index (AQI) observed in farms. Precise measurements are made regarding the microclimatic conditions of livestock environments, including temperature, relative humidity, and air quality. These environmental indices along with data gathered through the GPS

trackers are used to develop a complex index pertinent to the Sustainability Assessment of Food and Agriculture Systems (SAFA) of Food and Agriculture Organization of the United Nations (FAO) guidelines.

4. Wellness Platform

As part of the project, a platform is developed with the purpose of collecting real-time data and providing the capability to read, process, and display details in a user-friendly manner. Specifically, the application will support three roles: farmers, veterinarians, and cheese makers. For farmers, the platform will offer the ability to the user to monitor the animals, including their location, veterinary history, and welfare index, as shown in Fig. 5. Farmers can receive weather data from the installed agrometeorological station on their farm (Fig. 6) and view information about their production, such as the number of milking animals and details related to the quality and quantity of the milk produced, as shown in Fig. 7. Veterinarians will have access to all the aforementioned capabilities, allowing them to view data for each farm, as well as, to input key welfare indicators of individual animals, such as udder asymmetry, fibrosis, and abscesses, overgrown claws and arthritis, and head skin lesions and injuries. The application also will offer the capability to alert the farmer about potential health issues concerning their animals. Lastly, cheese makers will be able to input data regarding the quality and quantity of the milk they receive from each farm, thereby enabling the tracking and evaluation of milk production progress.

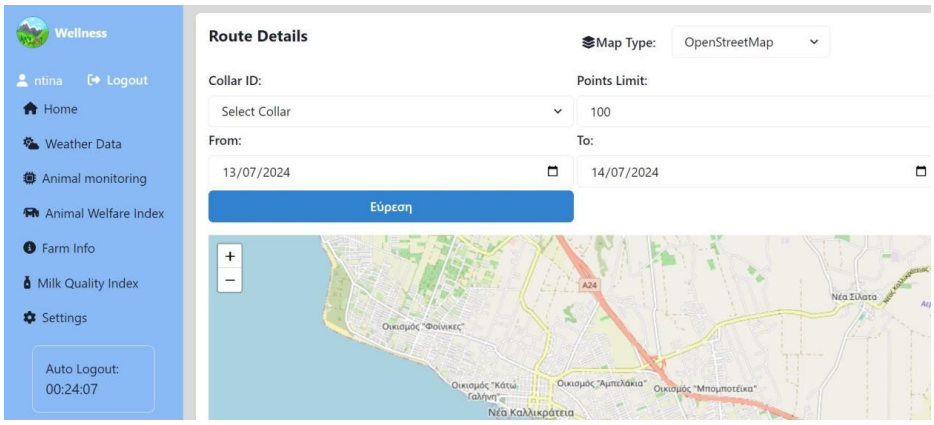

Figure 5: User Interface of the WELLNESS Platform: Animal monitoring

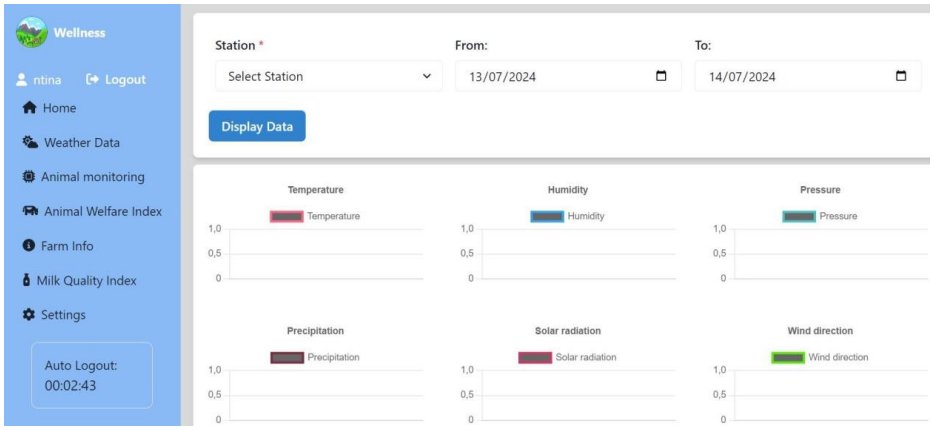

Figure 6: User Interface of the WELLNESS Platform: Weather data

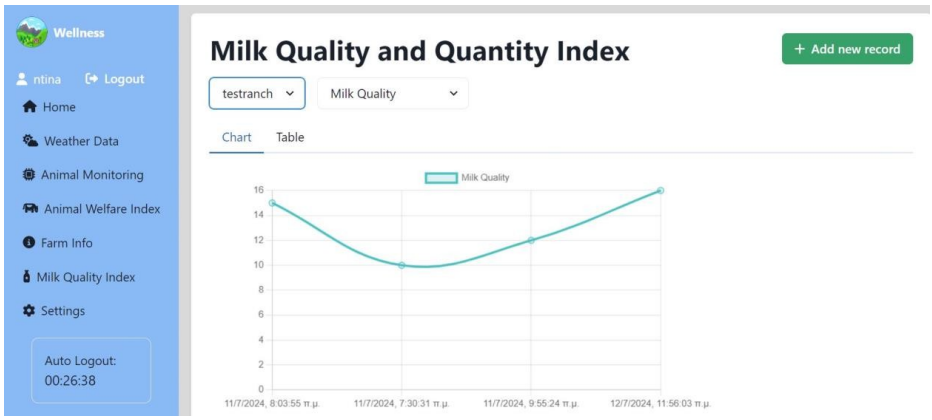

Figure 7: User Interface of the WELLNESS Platform: Milk quality and quantity index

5. Conclusion and future work

The WELLNESS project effectively illustrates the advantages of IoT technologies in livestock management. The use of IoT sensors, smart collars, and a specialized platform can lead to more precise and efficient operations, improving productivity, sustainability, and milk quality. By deploying a comprehensive system for real – time data collection and analysis, the project significantly enhances the monitoring and management of sheep and goat farms in milk – producing regions. The pilot implementation in Kozani, Greece, demonstrates the system's effectiveness in optimizing farm management and milk production processes. The tailored functionalities for farmers, veterinarians, and cheese makers will facilitate informed decision-making to ensure high-quality milk production and economic viability for agro – livestock enterprises. The upcoming activities of the project include the collection of data from the meteorological stations, which will additionally be used to develop the welfare index, based on the microclimate conditions of the farm area.

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Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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