A LoRaWAN-Based Infrastructure for Meteorological Data Collection to Support Software Systems in Agriculture

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Abstract. *This paper describes the deployment of a LoRaWAN-based infrastructure in the municipality of Santa Rosa, RS, Brazil, integrating meteorological stations, gateways distributed across urban and rural areas, and a software stack composed of ChirpStack, Node-RED, and PostgreSQL for continuous environmental data acquisition. Unlike purely conceptual approaches, this work presents a real operational environment and its applications. The collected data include temperature, humidity, precipitation, wind, luminosity, and UV radiation, which are made available through dashboards for real-time monitoring. The main contributions are: (i) the implementation of a functional infrastructure, (ii) support for agricultural applications based on real-world data, and (iii) the identification of indicators and use cases to support decision-making, such as phytosanitary risk analysis. Finally, perspectives for system evolution, evaluation, and future research are discussed.*

1. Introduction

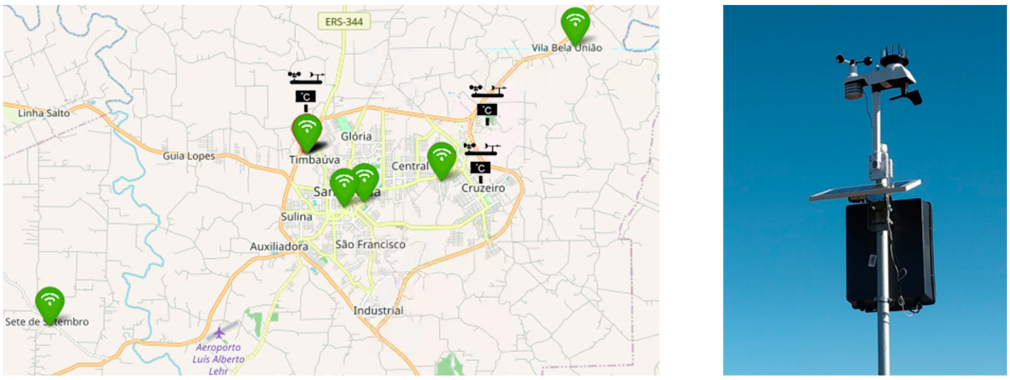
The Northwestern region of the state of Rio Grande do Sul, Brazil, is characterized by intense agricultural activity, with particular emphasis on the municipality of Santa Rosa, considered the "national birthplace of soybean production". The municipality concentrates grain production and agribusiness-related activities and hosts the project presented in this paper. This paper presents two ongoing projects aimed at deploying an infrastructure for data collection, transmission, and storage in Santa Rosa, with a technical and descriptive approach focused on data use in the agricultural context. The organization of the deployed infrastructure, the achieved coverage area, and the placement of antennas and meteorological stations are discussed, as well as the potential application of these data in the development of software systems for agriculture. The collected data support field operation planning and the monitoring of environmental conditions throughout the production cycle, motivating the development of decision-support software systems that rely on local data collection infrastructures. This initiative is conducted by the Regional University of Northwestern Rio Grande do Sul State (UNIJUÍ) and is linked to two institutional projects developed in the municipality, SmartLive Lab and Living Lab Agro Noroeste Missões. The technical aspects of the system and its potential agricultural applications are discussed in the following sections. The remainder of this paper is organized as follows: Section 2 presents the institutional projects and their objectives; Section 3 describes the deployed infrastructure; Section 4 discusses research contributions and applications developed based on the infrastructure; Section 5 outlines potential use cases and future directions; and Section 6 provides acknowledgements.

2. Institutional projects and objectives

The infrastructure presented in this work is part of two institutional initiatives developed in partnership with the Municipality of Santa Rosa and supported by the Secretariat of Innovation, Science and Technology of Rio Grande do Sul (SICT/RS). The Smart LiveLab focuses on the prototyping of IoT-based solutions and enabled the deployment of a LoRaWAN network with coverage in both urban and rural areas. Complementarily, the Living Lab Agro Noroeste Missões focuses on the use of the collected data for agricultural applications, including environmental monitoring, phytosanitary risk analysis, and decision-making support. The integration of these initiatives enables the development of software applications based on real-world data, leveraging the underlying connectivity infrastructure.

3. Infrastructure overview

The LoRaWAN infrastructure is composed of gateways equipped with external omnidirectional antennas, distributed to cover urban areas and part of the rural area of Santa Rosa [Sawicki et al. 2025]. Sensors and meteorological stations connected to the network collect data such as temperature, relative humidity, precipitation, wind speed and direction, luminosity, and UV radiation. These devices use low-power, long-range communication, which is well suited for large-scale agricultural scenarios. This connectivity enables continuous monitoring of environmental variables in the field, allowing efficient data collection and transmission over wide areas. Figure 1(a) shows the distribution of some gateways and meteorological stations in Santa Rosa, as well as an example of a deployed station in Figure 1(b).



(a) (b)

Figure 1. Spatial distribution of gateways and weather stations (a) and an example of an installed weather station (b).

Within the scope of the Living Lab Agro Noroeste Missões, the infrastructure is complemented by computational resources aimed at large-scale data processing, including equipment capable of advanced analytics, NVIDIA GPUs for experiments involving AI and machine learning, as well as drones equipped with LiDAR sensors for acquiring data on soil, vegetation, and topography. These additional data sources expand the range of information available for agricultural applications.

In terms of system organization, as illustrated in Figure 2, IoT sensors, represented by meteorological stations, transmit data to one or more gateways. These gateways forward the data to the ChirpStack network server, which is responsible for communication

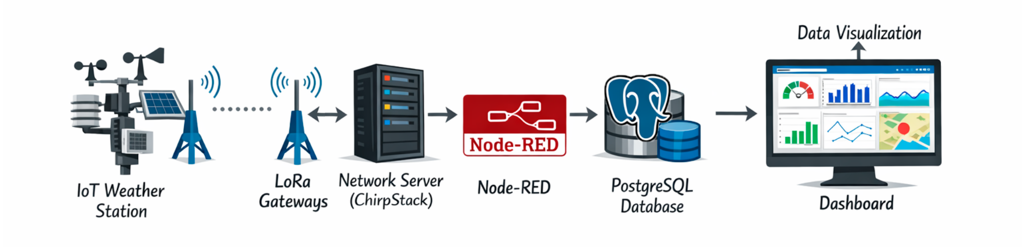


Figure 2. LoRaWAN-based Monitoring System Data Flow.

management and for making the data available to upper layers. The data are then processed through flows implemented in Node-RED and stored in a PostgreSQL database, which serves as the basis for visualization applications in operational dashboards[1] , as well as for analysis and decision-making support. This organization highlights the role of the infrastructure as a foundation for the development of software systems.

4. Research contributions and applications based on the infrastructure

The contributions presented in this work should be understood within the context of an ongoing project focused on the development and use of software systems supported by a real-world environmental data collection infrastructure. Although several studies have explored the use of LoRaWAN in agricultural contexts, many focus on conceptual proposals or experimental environments. In contrast, the deployed infrastructure has served as a basis for conducting research and developing software applications in a real-world scenario, encompassing its operational deployment as well as the consumption and exploration of data collected through the LoRaWAN network. This includes both agricultural applications and environmental condition analysis, highlighting practical aspects of component integration and effective data usage.

One of the works developed based on this infrastructure is a software system for real-time analysis of the favorability conditions for the occurrence of Asian soybean rust, using meteorological data collected through the LoRaWAN network deployed in Santa Rosa and surrounding areas. This system was developed as part of a master's thesis, as described in [Kuhn 2024], and integrates temperature and humidity data to compute disease favorability indices. The solution was designed to operate in integration with the existing infrastructure, consuming stored data and providing information through visualization interfaces, thus characterizing the infrastructure as a foundation for decision-making support applications in the agricultural domain.

Similarly, the work presented in [Valente et al. 2025] aimed to support smart city initiatives through the development of a software system focused on optimizing the placement of LoRaWAN gateways in order to expand network coverage under geographical and operational constraints. This system was developed in close interaction with the infrastructure and the technical expertise accumulated by the research group, particularly regarding the operational principles of LoRaWAN technology.

Furthermore, the data collected by sensors connected to this infrastructure are stored as time series, forming a dataset that, over time, supports new investigations, experiments, and future work. This dataset represents a valuable resource for analyzing and evaluating software solutions applied to different environmental scenarios. During

[1] https://livelab.unijui.edu.br

deployment, the importance of proper gateway placement to maximize coverage was observed, as well as challenges related to communication reliability and data quality, reinforcing the need for continuous validation of the infrastructure and adjustments according to the deployment environment.

5. Possibilities

The described infrastructure expands the use of meteorological data in the agricultural context by providing continuous and progressively more spatially distributed information. As the network expands, it becomes feasible to develop systems for real-time climate monitoring, analysis of environmental patterns associated with disease risk, and investigation of spatial variability in cultivated areas.

From a Software Engineering perspective, this infrastructure establishes a favorable environment for the design and evolution of data-driven applications, including visualization systems, exploratory analysis tools, and decision-making support systems. The availability of data from heterogeneous sources, such as distributed field sensors and drone-based data, creates opportunities to study data integration strategies and scalability mechanisms applied to agribusiness and local microclimate analysis.

Furthermore, the infrastructure opens avenues for future investigations related to data quality, communication reliability, and the adaptation of software systems to different production and territorial contexts. In addition, the evaluation of the infrastructure and its associated applications can be conducted using key performance indicators (KPIs), such as network availability, data delivery rate, volume of collected data, geographical coverage, and measurement reliability. At the application level, indicators such as the accuracy of meteorology-based models and their impact on agricultural decision-making can also be considered. These indicators enable the assessment of the infrastructure's effectiveness and guide its evolution. Consequently, these aspects support contributions in both the applied domain—by enabling more informed agricultural practices—and the methodological domain, by allowing the evaluation of software engineering solutions in real-world and dynamic environments.

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