Available online at https://asric.africa/engineering-sciences
ASRIC Journal on Engineering Sciences Vol.4(2)(2024) 141-148

Cutting-Edge Approaches to Mitigate the National Agro-Digital Deficit Towards Angola 2050

Cândido Pascoal Kudinahessa Kiluando[1]& Ngombo Makaya Armando[2]

[1]Sister Páscoa Sandrini School Campus, Street A Puri-Angola, ckiluando@gmail.com
[2]Department of Informatics Engineering - Kimpa Vita University, Bairro Kondo Benza 077 Uíge-Angola, ngombo@ieee.org

Received 2 April 2024; revised 22 April 2024; accepted 8 June 2024

Abstract

Food insecurity in Angola has been increasing since 2013, with an exponential trend since 2017. Such observations are partially explained by low agricultural productivity and high production costs. Angolan population is expected to double by 2050, which also challenges us for innovative solutions to answer to basic human needs, such as food. In this context, we have prototyped a digital platform for intelligent management of agricultural fields, leveraging off-the-shelf cutting-edge technologies for Internet of Things (IoT), namely ESP32, DHT22 sensor, LoRaWan, and FIWARE middleware. Our literature review followed PRISMA recommendations and was complemented by consultations with agriculture scholars to identify elementary environmental parameters for agri-productivity. We have assessed the proposed platform in both simulative and experimental ways. The communication infrastructure for our prototype registered an average data transmission rate of 5kb/s, with 100% delivery and an average latency of 60 seconds, thus ensuring real-time visualization. The maximum transmission distance was over 5 km, with a cost per sensing module (temperature and humidity) under $50. These results confirm the feasibility of a low-cost and robust infrastructure to mitigate the agro-digital deficit in Angola. Future challenges include implementation in real environments to optimize precision management, crucial for national food security and any business use-case that can be supported by IoT.

Keywords: Smart Agriculture, LoRa/LoRaWAN, FIWARE, IoT, Angola 2050.

I. Introduction

Despite a decline of 13+ percentage points between 2000 and 2020, the agricultural sector continues to employ over a quarter of the global workforce. During this same period, there was also an increase of over 100 million people suffering from undernutrition worldwide (FAO, 2018a). According to the Food and Agriculture Organization of the United Nations (FAO, 2018b), the world must produce 70% more food by 2050 than it did in 2006 to feed the growing population. To Welborn (2020a) "Angola is one of the seven countries globally that will inevitably experience a decline in the production of key crops, namely cassava, maize, sorghum, rice, wheat, and millet by 2030 due to climate change". Similarly, the Angolan agricultural sector, "once one of the most productive in the African continent, is now performing far below its potential" Welborn, 2020b).

In Angola, the number of people facing food insecurity has been rising since the 2013-2015 triennium, with an almost exponential trend observed from 2017-2019 (FAOSTAT, 2021). In this context, efficient yet sustainable agriculture and the preservation of the green ecosystem could help us to face the Angolan demographic growth projected to exceed 200% by 2050 (Welborn, 2020c). In fact, Angola's rich green ecosystem could provide good living conditions for its inhabitants amidst the high demand for food and extreme climatic conditions. However, among other aspects, challenges remain in implementing precision technology to increase productivity while reducing both costs and the waste of strategic agricultural resources, i.e., water, land, climate. Smart agriculture is increasingly seen as one of the solutions to these global sustainability challenges, as it fosters more efficient farming models (FAO, 2018). Such a productive dynamic is increasingly associated with automation, through both mechanization and the digitalization of agricultural processes. Since 2010, the digitalization of the agricultural sector has been primarily driven by the application of the Internet of Things (IoT) in agriculture (V. Bhatt et al., 2022). This approach, known as smart agriculture or Agriculture 4.0, includes innovative capabilities such as the ubiquitous and pervasive measurement of various critical agricultural parameters (Rama & Srikanth, 2015). Essentially, IoT enables better analysis, processing, and management of strategic resources, aiming for higher production capacities to meet growing demands.

With the massive development of low-power communication technologies and agricultural sensors, adopting this agricultural paradigm has become increasingly feasible. Thus, this study aims to develop a digital platform to support intelligent agricultural field management, based on proven digital technologies such as LoRa/LoRaWAN (Long Range Wide Area Network) for data transmission and FIWARE for contextual data management (N. Armando et al., 2022). Moreover, this study seeks to assess the implementation level of agricultural digitalization techniques in Angola, within the context of executing political programs to foster food resilience, notably the Strategic Food Reserve (Rea, 2022) and the National Grain Production Promotion Plan (Planagrão, 2022).

The rest of this paper is structured as follows: In Section 2 we present the related works. In section 3, we present the developed prototype and show the results obtained from its evaluation, before their analysis and discussion, in section 4. We conclude this paper in Section 5, identifying some opportunities for future research.

1. Methods, Techniques, Studied Material, and Area Descriptions

The literature review was conducted according to the criteria recommended by the PRISMA guidelines (Page et al., 2021), with a temporal cut-off from 2020 to 2022. During the search process, 971 records were found in the scientific databases IEEEXplore, ScienceDirect, and SciELO (see attached PRISMA flowchart in Appendix I). The following keywords were used to search for the records: LoRaWAN, FIWARE, Smart Agriculture, and Smart Farming, both in Portuguese and English.

2.1 Related Works

Smart Agriculture

Jani and Chaubey (2022) introduce a monitoring system using IoT devices to collect contextualized data on soil, air, water, and insects. Their solution facilitates informed decision-making through sensor data analysis. It integrates three models: firstly, a pest control system that automatically gathers insect information from field cameras, drones, or mobile devices. Secondly, an ultrasonic animal and human repellent with Passive InfraRed sensors and field cameras detects unauthorized entry, triggers sound waves, and alerts farmers via a mobile app panel. Thirdly, a drip irrigation system regulates water valves based on soil moisture data, halting irrigation and notifying farmers of water quality issues in real time. In (Koteish et al., 2022), an efficient soil moisture detection mechanism for field irrigation improvement is proposed. Unlike previous studies, this mechanism divides the monitored field into small zones called grids, each equipped with a leading sensor node. The solution, referred to as AGRO, operates in three phases, namely: intelligent sensing, energy efficiency, and decision-making. The first phase detects soil moisture conditions and updates the farmer on field status progress, minimizing data transmission to the gateway. The second phase analyzes field condition variations over successive periods and adjusts sensor detection frequency to conserve energy, thereby extending sensor lifespan. The final phase involves studying data collected by sensors, enabling farmers to act based on a predefined decision matrix. Ruiz-Ortega et al., (2022) present a low-cost IoT-based architecture project for monitoring climatic conditions, specifically air temperature, relative humidity, solar radiation, and wind speed within a greenhouse. The proposed architecture integrates WiFi (Wireless Fidelity) and GSM/GPRS (Global System for Mobile Communications/ General Packet Radio Services) wireless technologies for data transmission to the server. Monitoring climatic conditions within the greenhouse is identified as a key factor for improving agricultural production. Similarly, the study by (Roy et al., 2021) presents a dynamic irrigation scheduling system (AgriSens) that uses an algorithm for efficient water management in irrigated fields. AgriSens provides real-time, automatic, dynamic, and remote irrigation treatment for different growth stages of a crop's lifecycle. The system employs a low-cost sensor to measure the water level in a field and delivers field data to farmers in a multimodal manner. Compared to previous studies, this system shows significant results in various performance metrics, such as data validation, packet delivery rate, energy consumption, and failure rate under different climatic conditions and dynamic irrigation treatments. The system helps improve crop productivity by up to about 10% compared to manual irrigation methods. Furthermore, the authors claim to extend the sensor network's lifespan by 2.5 times more than existing systems, achieving 94% reliability even after 500 hours of operation.

LoRaWAN and FIWARE Enablers

Munoz et al., (2022) proposes a cloud-based IoT system to build a platform applied in a greenhouse production context that provides historical data services, current values, weather forecasts, climate model, tomato production model, and irrigation model, available through an Application Programming Interface (API) service. Here, historical and real-time data, as well as forecast models, are accessed via RESTful web services, using FIWARE platform, which provides a range of functionalities and standards, facilitating the development of intelligent applications. The platform integrates a service called GMaaS (Greenhouse Models as a Service) that uses greenhouse models to estimate indoor climate, agricultural production, and irrigation values. The system is dynamic because all services are available through the API for different user needs. Despite the limitations in the use of the models by users, which are intended for research purposes only, GMaaS provides cloud-based models without any dependency on software or devices. In (Franco et al., 2020), the authors developed a seed germination monitoring system that uses image processing techniques and fuzzy logic. The system is based on the Cloudino-IoT platforms and, like the study by Munoz et al., (2022), it leverages FIWARE middleware. The system controls variables through fuzzy control techniques, and image processing monitors the germination of the seed radicle. For the development of the system, combined open-source platforms are used, enabling cloud computing to maintain, specify, analyze data, and automate environmental parameters, allowing temperature and humidity to be kept at optimal levels to create a favorable germination environment.

Hernandez et al., (2021) developed an IoT prototype using LoRa communication and FIWARE services. The prototype uses humidity, temperature, and geolocation sensors connected to SODAQ ExpLoRer boards for data collection. The information collected by the OpenSource components and services of LoRa, LoRaWAN, and ChirpStack is transferred to the Context Broker and then used in various FIWARE services, CrateDB, and Grafana. Unlike the study by (Munoz et al., 2022), the system showed communication incompatibility due to the different protocols and languages used in the devices, prompting the creation of alternative solutions, such as LPWAN (Low-power Wide-area Network) using open and standardized platforms. This allows efficient data transmission to the FIWARE platform even without nearby internet access to the data receiver device. The FIWARE platform uses a LoRaWAN IoT agent that ensures compatibility with the communication protocol used on the ChirpStack platform. Other similar platforms, such as TTN (The Things Network), can also be used (TTN, n.d.). The prototype showed satisfactory performance results despite the limitations of transportation, weather conditions, and internet connectivity during the system's performance test.

National Agricultural Strategy

To enhance national production, particularly in rice, maize, wheat, and soybean crops, Angola aims to foster domestic production towards achieving food sovereignty. This strategy involves investing in agricultural support technologies and creating intrinsic conditions to manage national production autonomously, thus, minimizing dependence on imports and external expertise. Our literature review identified a gap in precision agriculture studies in Angola, aligned with ambitious policies like the Strategic Food Reserve (Portuguese acronym - REA) and the National Grain Production Development Plan (PLANAGRÃO). The Government Program 2022-2027 aims to position Angola as a leading agricultural and livestock producer in Africa, focusing on large-scale cereal production. Key goals include improving conditions for farmers to increase production profitability, enhancing food resilience for security and institutionalizing agricultural research with technology support and sector digitalization. *PLANAGRÃO* program specifically targets wheat, rice, soybean, and maize production, aiming to reduce import dependency and accelerate local production. Additionally, the REA ensures food security by stabilizing prices and preventing speculative practices, supporting national production scaling to reduce import reliance. Complementing these efforts, the *PRODESI* program aims to enhance economic diversification through prioritized production sectors and clusters, promoting innovation, business growth, and technological synergies. In nutshell, Angola's strategic focus on agricultural diversification and technology integration presents significant opportunities for future research, particularly in digital agriculture solutions and infrastructure development aligned with global standards.

Gaps in the Literature and Research Opportunities

It is crucial to highlight the gap in case studies on precision agriculture in Angola. The temporal scope of this review coincides with the country's emphasis on "food resilience" through ambitious programs namely the *REA* and *PLANAGRÃO*. In this context, we identified research opportunities to mitigate the national agro-digital technological deficit, as recommended by the *PRODESI*, which will be detailed in next point.

2.2 Prototype Architecture

The overall architecture of the prototype is presented in Fig. 1. It consists of a sensor node, responsible for collecting temperature and humidity data and transmitting them via LoRa technology to the gateway. The gateway receives this data and forwards it over the internet to the FIWARE server, which executes services in a virtualized manner using Docker virtualization technology. Once the information is sent to the server, it is stored and processed in databases such as MySQL and MongoDB, and subsequently displayed in real time through dashboards.

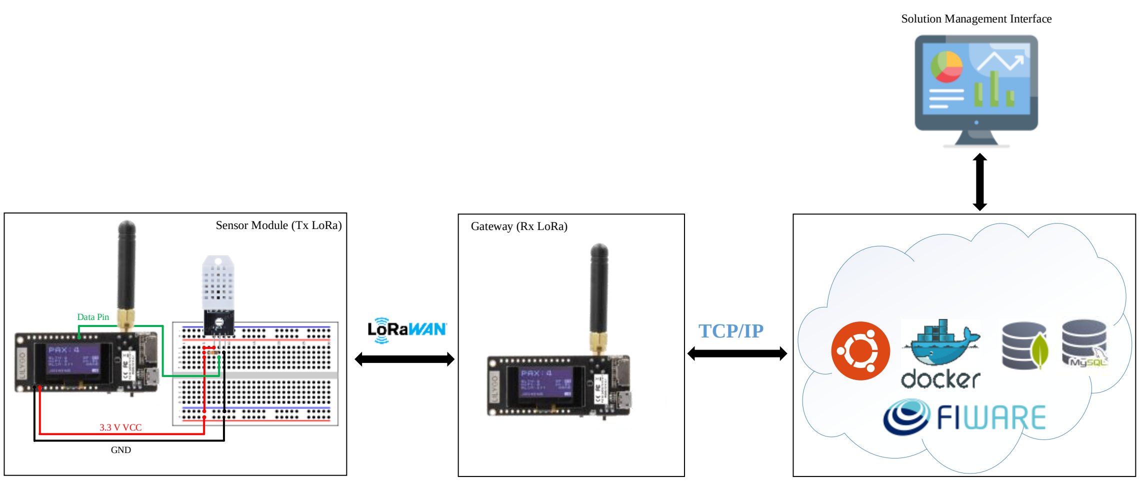

***Fig. 1** - Prototype Architecture*

Methods and Materials

Our study adopts an experimental approach, involving the design and implementation of a prototype for measuring and monitoring temperature and humidity. The prototype's validation included simulation and operational tests in both laboratory and real-world environments, aimed at assessing its effectiveness. The methodological procedures followed several distinct stages. In addition to the literature review, interviews were conducted with two faculty members/researchers from the Department of Agronomy at Kimpa Vita University (UNIKIVI), Uíge city -Angola. These interviews aimed to identify fundamental environmental parameters affecting agricultural productivity, specifically focusing on temperature and humidity.

Following these preparatory stages, the prototype was designed and implemented. Overall, the methodological approach ensured a robust foundation for studying the application of IoT in agriculture, particularly in precision farming, by integrating theoretical insights with practical experimentation and validation.

IoT devices

For the development of the platform prototype, we leveraged the components in Table 1. The following section present the results obtained from the prototype. The experiments included the profile of the monitored area as well as communication metrics.

Table 1 *- Device Specifications*

Device	Specifications
Esp32 Lora32 V1.6.1 Microcontroller	LoRa transceiver (SX1276/SX1278), 14dBm + 14dBm PA, 433/868/915MHz frequencies, 0.96" OLED display 128x64, Wi-Fi 802.11, Bluetooth V4.2, 3.7V power supply.
DHT22 Sensor (AM2302)	*Temperature* sensor: -40°C to 80°C, ±0.5°C accuracy. Relative humidity sensor: 0% to 100%, ±2% accuracy (20% to 80%).
Jumpers	Components for temporary connections between devices.
Protoboard	Board for solderless circuit assembly and testing, conductive tracks interconnecting components.
3.7V 2000mAh Lithium Polymer Battery	Rechargeable, high energy density, 3.7V voltage, 2000mAh capacity.
Resistor	10,000-ohm resistance, ±5% tolerance, used in various electronic applications.

Experimental Environment Tests

The real-world tests aimed to assess the system's effectiveness and feasibility across four zones displayed in Appendix II. Zone 1: between the Botanical Garden and IP/UNIKIVI (Polytechnic Institute /Kimpa Vita University), spans approximately 0.5 km. Zone 2: covering about 5.48 km, extends from Cassexe Village to IP/UNIKIVI. Zone 3: approximately 3 km, connects Kunga Kixima Village and IP/UNIKIVI. Finally, Zone 4; around 3.40 km, includes the area from the Kilomosso Roundabout to IP/UNIKIVI.

The system was eventually installed in Zone 1 for security reasons. Moreover, the Botanical Garden offers a better environment for research studies as it is part of agricultural practices of agronomy students. In this context, the other zones were exploited for calibration proposes, i.e., communication and accuracy. Results presented in the following section cover data gathered in Zone .

2. Results

The collected data from the results is available on GitHub and can be accessed through the following link: https://github.com/Kiluando88/Collected data.git](https://github.com/Kiluando88/Collected-data.git.

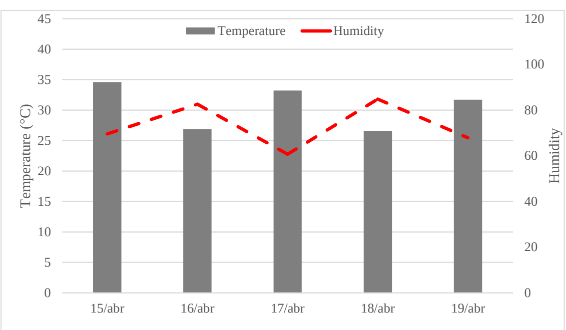

Fig. 2 *- Temperature and Humidity Reading*

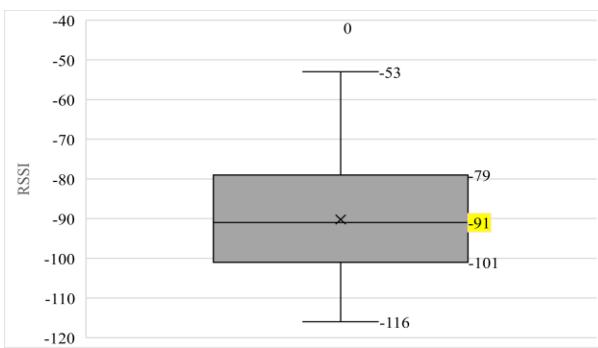

Fig. 3 *- RSSI Distribution*

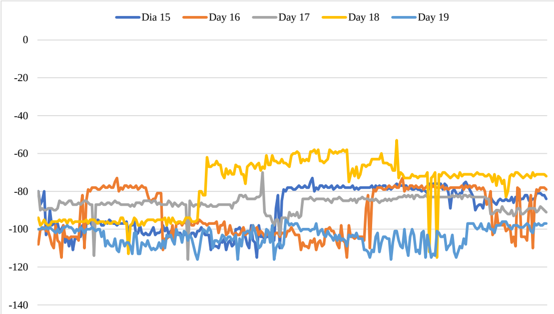

Fig. 4 - *Daily RSSI Variation*

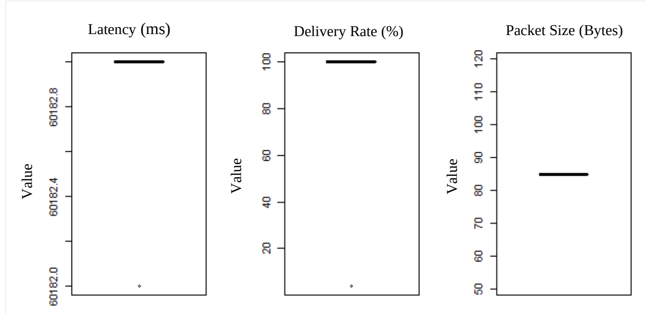

Fig. 5 - *Distribution of Latency, Delivery Rate, and Packet Size*

3. Discussion

Monitored Area Profile

As illustrated in Fig. 2, the *temperature* and humidity measurements over the five days provided meteorological insights, highlighting seasonal patterns and climatic fluctuations. Temperature peaks reached 39ºC in the mornings, followed by declines to 24ºC in the afternoons, which results in a daily average of 32ºC influenced by the solar cycle. Relative humidity varied, with high values of 96% on rainy days, an average of 64%, and low humidity periods down to 32%, typical of drier climates. The analysis reveals negative correlations between *temperature* and humidity.

RSSI Distribution

Figure 3 is a distribution of RSSI (Received Signal Strength Indication) data, providing a visual representation of dispersion in relation to quartiles and minimum and maximum values. The data show a left-skewed distribution. Radio link can be considered has good when RSSI > -115dB, which is the case of the obtained RSSI in our experiments are all. The presented RSSI data, when compared to other indicators such as SNR, are also deemed effective according to the literature (Sensing Labs, 2020).

Temporal Variation of RSSI

In Fig. 4, we can see that between the fifteenth and nineteenth, signal quality varied significantly. On the fifteenth, RSSI ranged from -115 to -75, indicating instability in signal quality. On the sixteenth, the range was -115 to -73, maintaining this instability. On the seventeenth, RSSI values ranged from -116 to -70, with a trend of declining values throughout the day. On the eighteenth, RSSI values improved, ranging from -115 to -53, showing relatively stable quality despite fluctuations. On the nineteenth, RSSI varied from -116 to -95, with a declining trend impacting signal quality. Overall, signal quality was variable and subject to instability, influenced by physical obstacles and adverse weather conditions.

Latency, Packet Size, and Success Rate

Constancy in latency, delivery rate, and packet size is crucial, especially for precision agriculture (Pagano et al., 2023). The collected data showed a latency of 60.183 ms, a packet size of 85 bytes, and a delivery rate of 100% (see Fig. 5). This performance indicates that there were no communication delays, all packets were successfully delivered, and the data size was constant. For precision agriculture, these results are excellent. In fact, a 100% delivery rate ensures complete transmission of information, and low latency is crucial for real-time decisions, such as crop monitoring.

Correlations between Variables

The Pearson correlation coefficient between time and RSSI is approximately 0.3119, suggesting a moderate positive correlation. However, given that this value is relatively low, it indicates that the relationship between time and RSSI is not strong. The Pearson correlation test confirmed this interpretation, with a t-value of 11.926 and a very low p-value (< 2.2e-16), indicating that, although the correlation is statistically significant, the association between the variables is weak. The 95% confidence interval for the correlation ranges from 0.2624 to 0.3597, reinforcing the idea that the relationship between time and RSSI is positive but not substantial. In summary, while there is a moderate positive correlation, the relationship between time and RSSI is not strong and does not suggest a significant association between the variables.

5. Conclusions

This study aimed to develop a digital platform for intelligent management of agricultural fields using IoT technologies such as LoRa/LoRaWAN and FIWARE. Through a methodological approach involving literature review and consultation with agricultural science experts, essential monitoring variables like temperature and humidity were identified. A validated prototype was designed and tested through simulations and real-world experiments. Results demonstrate the platform's viability and effectiveness: average data transmission rate of 5kb/s with 100% delivery reliability, latency of approximately 60 seconds, and a maximum transmission distance of 5.48 km. This platform offers a cost-effective solution for enhancing productivity, reducing costs, and minimizing waste in Angolan agriculture, promoting sustainable practices and improving food security.

Future research opportunities include integrating additional monitoring variables (e.g., soil quality, wind speed, precipitation patterns) and the inclusion of actuators. We also plan to expand the platform's scalability to other regions and crops and assess socio-economic and environmental impacts of the current agricultural practices.

6. Acknowledgements

The authors are grateful to the Rector of Kimpa Vita University, Prof. Pedro Vita, and the Director of the Polytechnic Institute, Prof. Citenge Kakwata, for allowing them to carry on the field study in the institution. The authors are also thankful to Macuntima Pedro and Eduardo André Quicongo, form the Department of Agronomy at Kimpa Vita University for their expertise in identifying the elementary environmental parameters for agri-productivity.

7. References Cited

Armando, N. Sinche, S., Rodrigues, A., Silva, J. S. & Boavida, F.(2022). IoT Management Services: A Comparative Assessment of Popular FIWARE Agents. *IEEE Ninth International Conference on Communications and Electronics (ICCE), Nha Trang, Vietnam*, 81–86.

Bhatt, V., Pathak, P., Sinha, B., & Ramesh. G. (2022). Intelligent Agricultural Management System Based on IoT: Opportunities and Challenges. *International Conference on Data Analytics for Business and Industry (ICDABI), Sakhir, Bahrain*, 747–750.

FAO. (2018). The future of food and agriculture—Alternative pathways to 2050. Food and Agriculture Organization of the United Nations, Rome, Italy. *Food and Agriculture Organization*.

FAOSTAT. (2021). *Food and Agriculture Organization of the United Nations*.

Franco, J. D., Ramirez-delReal, T. A., Villanueva, D., Gárate-García, A., & Armenta-Medina, D. (2020). Monitoring of Ocimum basilicum seeds growth with image processing and fuzzy logic techniques based on Cloudino-IoT and FIWARE platforms. *Computers and Electronics in Agriculture*, *173*. https://doi.org/10.1016/j.compag.2020.105389

Hernandez, D. L., Arias, J., Villanueva, D., Gutierrez, S., & Zavaleta, I. (2021). IoT system prototype based on LoRa and the Orion Context Broker data model of FIWARE. *2021 23rd IEEE International Autumn Meeting on Power, Electronics and Computing, ROPEC 2021*. https://doi.org/10.1109/ROPEC53248.2021.9668028

Jani, K. A., & Chaubey, N. K. (2022). A Novel Model for Optimization of Resource Utilization in Smart Agriculture System Using IoT (SMAIoT). *IEEE Internet of Things Journal*, *9*(13), 11275–11282. https://doi.org/10.1109/JIOT.2021.3128161

Koteish, K., Harb, H., Dbouk, M., Zaki, C., & Abou Jaoude, C. (2022). AGRO: A smart sensing and decision-making mechanism for real-time agriculture monitoring. *Journal of King Saud University - Computer and Information Sciences*, *34*(9), 7059–7069. https://doi.org/10.1016/j.jksuci.2022.06.017

Lily Welborn, J. C. e S. K. (2020). *Cenários do Futuro de Angola 2050*.

Munoz, M., Guzman, J. L., Sanchez-Molina, J. A., Rodriguez, F., Torres, M., & Berenguel, M. (2022). A New IoT-Based Platform for Greenhouse Crop Production. *IEEE Internet of Things Journal*, *9*(9), 6325–6334. https://doi.org/10.1109/JIOT.2020.2996081

Pagano, A., Croce, D., Tinnirello, I., & Vitale, G. (2023). A Survey on LoRa for Smart Agriculture: Current Trends and Future Perspectives. *IEEE Internet of Things Journal*, *10*(4), 3664–3679. https://doi.org/10.1109/JIOT.2022.3230505

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. In *The BMJ* (Vol. 372). BMJ Publishing Group. https://doi.org/10.1136/bmj.n71

Rama, G. V, & Srikanth, L. V. (2015). International Journal of Advanced Research in Computer Science and Software Engineering Location-Based Routing Protocol in Wireless Sensor Network-A Survey. *International Journal of Advanced Research in Computer Science and Software Engineering*, *5*(4).

República de Angola. Conselho de Ministros. (2022). Decreto Executivo Conjunto n.º 208/19, de 9 de Agosto, I Série, n.º 102. Regulamento da Reserva Estratégica Alimentar. Imprensa Nacional. Angola, disponível em https://faolex.fao.org/docs/pdf/ang188843.pdf. (2022). https://faolex.fao.org/docs/pdf/ang188843.pdf

República de Angola. Conselho de Ministros. (2022). Decreto Presidencial n.º 200/22, de 23 de Julho, I Série, n.º 138. Aprova o Plano Nacional de Fomento para a Produção de Grãos. Imprensa Nacional. Angola, disponível em https://plataformacipra.gov.ao/public/ficheiros/arquivos/Gov_AngolaDecreto%20Presidencial441312221233401670931220.pdf. (2022). https://plataformacipra.gov.ao/public/ficheiros/arquivos/Gov_AngolaDecreto%20Presidencial441312221233401670931220.pdf

Roy, S. K., Misra, S., Raghuwanshi, N. S., & Das, S. K. (2021). AgriSens: IoT-Based Dynamic Irrigation Scheduling System for Water Management of Irrigated Crops. *IEEE Internet of Things Journal*, *8*(6), 5023–5030. https://doi.org/10.1109/JIOT.2020.3036126

Ruiz-Ortega, J., Martínez-Rebollar, A., Flores-Prieto, J., & Estrada-Esquivel, H. (2022). Design on a low Cost IoT Architecture for Greenhouses Monitoring. *Computacion y Sistemas*, *26*(1), 221–232. https://doi.org/10.13053/CyS-26-1-4166

Sensing Labs. (2020). *Sensing Labs. (n.d.). A good radio level*. https://sensing-labs.com/f-a-q/a-good-radio-level/

TTN. (n.d.). *The Things Network. (n.d.)*. Retrieved August 10, 2024, from https://www.thethingsnetwork.org/

List of Abbreviations

API	Application Programming Interface
FAO	Food and Agriculture Organization
GMaaS	Greenhouse Models as a Service
GPRS	General Packet Radio Services
GSM	Global System for Mobile Communications
IoT	Internet of Things
IP/UNIKIVI	Polytechnic Institute /Kimpa Vita University
LoRa	Long Range
LoRaWAN	Long Range Wide Area Network
LPWAN	Low-power Wide-area Network)
RSSI	Received Signal Strength Indication)
TTN	The Things Network
WiFi	Wireless Fidelity