IoT for agriculture optimization: preliminary results of a tropical precision farming project

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Abstract. The agricultural activities need optimal soil and the agro-climatic conditions in the production areas such as Cerro Punta in Panama. Among the innovative technological alternatives, there are tools that can provide farmers with information describing the agro-meteorological conditions of some areas, such as precision agriculture. Due to the data range of wireless communication and low power capabilities, one of the most promising technologies for precision farming is WSN with integrated LoRa systems and energy self-sufficient. This study presents the methodology of the first LoRa WSN project destined to precision agriculture in Panama, and bring the preliminary results in the evaluation of LoRa signal, micro solar panel efficiency and environmental data. In the tropical vegetation of this part of the country, the range of LoRa communication is smaller than theoretically expected. The efficiency of the solar panels is enough to maintain the batteries always charged. Finally, slightly different microclimates have been highlighted between two close monitored areas.

Keywords: Environmental monitoring, Internet of Things, Wireless Sensors Network, LoRaWAN, Received Signal Strength Indicator, Precision farming.

1 Introduction

The development of agricultural activities is closely linked to the state of the soil and the agro-climatic conditions of the production areas. Specific actions such as the estimation of river precipitation, temperature, photoperiod, physicochemical properties of the soil, among other variables, make it possible to identify the potential and limitations of different areas in a timely manner.

Precision agriculture is a valuable tool for accurately diagnosing agricultural production problems, making decisions and obtaining satisfactory responses in agricultural yield indices. It is vitally important to focus on the right place at the right time, based on the scientific innovations offered by information technology.

In the IoT environment, the technological development of Wireless Sensor Networks (WSN) offers a sustainable solution applied to precision agriculture. This type of network allows efficient use of agricultural resources, management tools and monitoring of different parameters to achieve higher quality yields and production [1]. The concept WSN can be extended under low-power wide area networks, a wireless technology for transmitting small data units over long distances with minimal power consumption. In a precision agriculture environment, the scope of LoRaWAN can be used to monitor crop health forecasting, ensuring suitable amounts of nutrients, disease detection, irrigation scheduling and weather monitoring [2].

Some research contributions present technical and theoretical approaches, mainly focused on the data collection, data analysis, diagnosis of forecast disease and field operation of precision agriculture techniques [3-5].

The development of institutional cooperation alliances is fundamental for the fulfillment of strategic objectives in the field of agricultural research and innovation. The Institute for Agricultural Innovation of Panama (IDIAP), in its mission to strengthen the national agro-technological base, together with the Autonomous University of Chiriqui (UNACHI), has achieved the procurement of sensors through the FIED19-R1-003 project, with the interest of linking Internet of Things (IoT) technologies to the experimental trials that are conducted daily at the IDIAP Experimental Station, located in Cerro Punta, District of Tierras Altas, Province of Chiriqui.

2 Materials and Methods

The experiments were managed in an experimental station of the Institute for Agricultural Innovation of Panama (IDIAP), located in Cerro Punta. The design of the IoT framework requires sensor nodes, LoRaWAN gateway, LoRaWAN Network Server and a monitoring solution for IoT applications. The experiments were conducted over onions parcels which combines practical WSNs deployment, with precise applicable solutions on the crops.

2.1 Wireless Sensors Network

Table 1. Parameters of LoRa nodes.

Parameters	Values
Spreading factor	7-12
Coding rate	4/5
Bandwidth	125 kHz
Frequency range	902-928 MHZ
Transmission power	-2.0 dBm

The implementation of LoRaWAN was chosen due to its low data transfer rate, low deployment and management costs. In tropical areas, agricultural plots are susceptible to different types of interference and diversification, requiring an improved LoRaWAN network design scheme. The IoT nodes devices are divided in tree crop areas, with a size range coverage of 1,000 m^2 and the gateway has a height of 3 m. The packets collected are transmitted through a LoRa network communication and then forwarded to LoRaWAN Gateway with LTE network connection. In order to transmit the packets, the LoRa Nodes adopt the spreading factor automatically between SF 7-12. The main parameters in field trials are given in **Table 1**.

2.2 Cerro Punta site case study

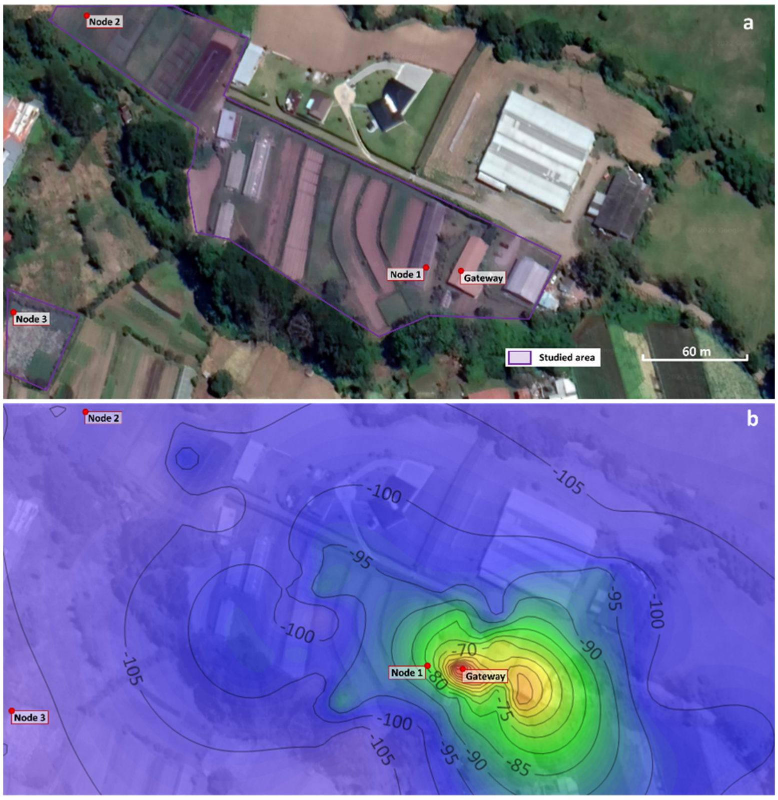

Figure 1. Sensor nodes and Gateway locations (a) and RSSI signal estimation map (b).

Cerro Punta is an important productive area of the country of Panama, the installed sensors have the capacity to collect data on parameters directly related to the productive cycle, development and growth of the main crops evaluated in the Highlands area.

In crops such as onions, the development of diseases such as Botrytis is favored by conditions of periods of high relative humidity and moderate temperatures. Periods of about six hours of wet leaves and temperatures below 24°C are sufficient for infection to occur. Under these conditions the fungal growth organisms (spores) have favorable conditions to reproduce [6]. Evapotranspiration is also affected by climate, management and crop development environment. The main climatic parameters affecting evapotranspiration are solar radiation, temperature and relative air humidity [7].

The Node 1 was placed close to the Gateway, at 20m, in a greenhouse of 4m high, 45m long and 9m wide while Nodes 2 and 3 were placed at 250m from the gateway, and 180m from each other in outdoor 400m^2 parcels (Fig.Figure **1**.a).

3 Preliminary results

To quantify the signal strength, an estimated isopleth has been created using Surfer software with Natural Neighbor as gridding method to simulate a signal strength map (Fig.Figure **1**.b). Comparing the RSSI results with those of a similar study with a max range around 200m against 400m for our study, Yim *et al.* [8] obtained a RSSI of -92, whereas we get a RSSI of -110 without significant packet-loss.

As for the efficiency of the solar panels in recharging the batteries, it was noted that with an average luminosity value of 8,000 lux.h^{-1}, the average charge rate is 0.03 V.h^{-1}, which represents 1% per hour of the maximum charge of the battery during 12 hours. The average discharge of the batteries is 0.01 V.h^{-1} without luminosity, during 12 hours of the night. As a result, the night discharge is completely compensated during the day.

In the greenhouse, node 1 detected low light and very low soil moisture compared to the outdoor sensors. In the latter two situations, nodes 2 and 3, demonstrated more diverse air temperature values than expected. Indeed, despite the short distance between the two nodes, it has been detected different variations over time between the two monitored sites, especially in the extreme temperature values in which node 3 showed a minimum of 1.17°C lower than node 2, and a maximum 4.60°C higher while relative humidity, soil moisture and soil temperature variations are the same on both sites. Sensor parameters and obtained values are detailed in Table Table **2**.

Table 2. Sensor nodes measurements during one week from February 25 to March 4, 2022.

Parameters		Node 1	Node 2	Node 3
RSSI signal (dB)	Average ± Std Dev	-80 ± 1	-113 ± 2	-112 ± 3
Battery (V)	Average ± Std Dev	4.02 ± 0.10	4.03 ± 0.08	4.00 ± 0.09
	Min - Max	3.81 - 4.20	3.90 - 4.19	3.86 - 4.18
Luminosity (Lux)	Average ± Std Dev	5,237 ± 9,946	7,606 ± 14,647	8,845 ± 15,526
	Min - Max	0 – 54,612	0 – 54,612	0 – 54,612
Temperature (°C)	Average ± Std Dev	19.13 ± 10.16	16.35 ± 7.31	15.44 ± 8.44
	Min - Max	5.03 - 46.80	4.39 - 35.90	3.22 – 40.50
Soil temperature (°C)	Average ± Std Dev	23.14 ± 5.76	18.51 ± 4.96	18.95 ± 5.55
	Min - Max	14.30 – 39.10	9.93 – 31.00	9.36 – 33.90
Relative Humidity (%)	Average ± Std Dev	74 ± 29	81 ± 21	81 ± 24
	Min - Max	14 - 100	26 - 100	19 – 100
Soil moisture (%)	Average ± Std Dev	5.6 ± 2.8	38.6 ± 11.3	40.13 ± 11.4
	Min - Max	0.1 – 11.0	30.5 – 74.2	30.4 – 74.3

4 Conclusion and future work

The aim of this paper was to assess the functioning of the first LoRa WSN destined to precision agriculture and farmers decision-making assistance in Panama. The preliminary results have been analyzed during the first week of monitoring. The signal range was smaller than in other studies due to the high vegetation density of the area. In terms on energy, the tropical environment is well adapted to the use of solar panels and the night discharge of the batteries was totally compensated during the day. From an environmental point of view, the microclimates differences have already been highlighted between two close monitored areas at less than 180 meters from each other. It has been observed up to 5°C differences in the air while soil temperature, soil moisture and relative humidity maintained stable between the two sites. Nonetheless, those differences suggested the necessity to adapt the local management of these two parcels. As future work, to obtain a better coverage range, LoRaWAN antennas with ranges of up to 20 km can be implemented and the acquisition of more data on local environmental conditions will allow the analysis of plant interactions contributing to the management of diseases, water use and the use of phytosanitary products and fertilizers.

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