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Review Study of Internet of Things (IoT) and its Applications in Scientific Research and Agricultural Production

Mohammed Abdullah Mohammed Al-Rawi¹ and Laith Joudah Kareem Al-Daini²

Department of Soil and Water Resources Sciences/ College of Agricultural Engineering Sciences/ University of Baghdad

Corresponding author: mohammed.alrawi@coagri.uobaghdad.edu.iq

Abstract:

The Internet of Things (IoT) expression refers to leveraging network connectivity and computing power to extend to objects, sensors, and everyday items not typically considered computers, allows to generate, exchange, and consume data with minimal human intervention. The most important feature of the Internet of Things is that connected devices get dynamic sensing and real-time response capabilities. This study highlights the use of Internet of Things (IoT) technologies in scientific research and agricultural work, where climate, laboratory, agricultural production, and scientific research data are received directly, instantly, and electronically documented. By this technology, improve the efficiency of the management of irrigation equipment, enhance laboratory workflows and ensure that equipment works smoothly under reliable and safe conditions, control and watch the environment of greenhouse and animal farming remotely, and ultimately enhance reliability and improve yields and profits.

Keywords: *laboratory information management systems, Wireless Sensor Network, Smart devices*

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دراسة مراجعة لإنترنت الأشياء وتطبيقاته في البحث العلمي والإنتاج الزراعي

ليث جودة كريم الدايني²

محمد عبدالله محمد الراوي¹

قسم علوم التربة والموارد المائية / كلية علوم الهندسة الزراعية/ جامعة بغداد

الخلاصة

يشير مصطلح إنترنت الأشياء (IoT) إلى الاستفادة من اتصال الشبكة وقوة الحوسبة وتوسيع نطاقها لتشمل الأشياء، وأجهزة التحسس، والمواد اليومية التي لا تُعتبر عادةً أجهزة حاسوب، مما يتيح لها توليد البيانات وتبادلها واستهلاكها بأقل تدخل بشري. أهم ميزة لإنترنت الأشياء هي حصول الأجهزة المتصلة على قدرات استشعار ديناميكي واستجابة آنية. تُسلط هذه الدراسة الضوء على استخدام تقنيات إنترنت الأشياء (IoT) في البحث العلمي والعمل الزراعي، حيث تُستقبل بيانات المناخ والمختبرات والإنتاج الزراعي والبحث العلمي مباشرةً وبشكل فوري وموثق إلكترونيًا. من خلال هذه التقنية، يتم تحسين كفاءة إدارة معدات الري، وتعزيز سير

العمل في المختبرات، وضمان عمل المعدات بسلاسة في ظروف موثوقة وآمنة، والتحكم في بيئة البيوت البلاستيكية وتربية الحيوانات ومراقبتها عن بُعد، مما يؤدي في النهاية إلى تعزيز الموثوقية وتحسين الغلة والأرباح.

الكلمات المفتاحية: نظم إدارة المعلومات المختبرية، شبكة المتحسس اللاسلكية، الأجهزة الذكية.

INTRODUCTION

The term Internet of Things (IoT) refers to leveraging network connectivity and computing power to extend to objects, sensors, and everyday items not typically considered computers. This allows these objects to generate, exchange, and consume data with minimal human intervention (Rose et al., 2015). Kankanhalli et al., (2019) defined the IoT as a network of objects and things containing electronics, software, sensors, and actuators that allow these objects to communicate, interact, and exchange data. This technology enables remote interaction with, control, and management of devices and data. Examples include early warning devices and surveillance cameras used in homes and institutions, as well as cameras and monitoring devices that detect traffic violations, as well as cybersecurity devices and applications related to threats to national security. The IoT can also develop and create numerous services for citizens in various fields, such as transportation, energy, education, and healthcare, making it a key and effective factor in e-governance. Generally, IoT system (including proposed hardware components) includes the following key elements: sensor communication, microcontrollers, actuators, and user interfaces (Wu et al., 2020; Mohammed, 2024). Many microcontroller devices which incorporated into Internet of Things (IoT) applications, developed by a board for the Arduino software environment (Barrett, 2020). This review study aims to highlight the use of Internet of Things (IoT) technologies in scientific research and agricultural work. Climate, laboratory, agricultural production, and scientific research data are received directly, instantly, and electronically documented through this technology.

Live and Real-Time Data Monitoring and Recording (weather data, etc.):

The most important feature of the Internet of Things is that the smart devices connected to it have dynamic capabilities for sensing and responding in real-time (Chatfield & Reddick, 2019). Dataloggers in these devices provide real-time data at the fingertips anytime, anywhere, and as desired. This saves the effort and time spent monitoring and collecting data. For example, in a smart electronic weather station, data is transmitted over the internet through the cloud via a station-specific application, and the meteorologist receives it directly through a console, daily and at all times, updated every 5 minutes or every hour, depending on preference, as shown in Figure (1). Furthermore, all data is documented in an electronic file and can also be received in the form of graphs. Similarly, data from any smart measuring device can be received for any purpose. Datalogger's mechanism includes cloud-based data delivery, Bluetooth and GPS settings, and integrated metadata, all of which simplify and accelerate the process of data collection, management, and sharing by entering the recipient's email and sharing on relevant websites. Datalogger's mechanism includes cloud-based data delivery, Bluetooth and GPS settings, and integrated metadata, all of which simplify and accelerate the process of data collection, management, and sharing by entering the recipient's email and sharing on relevant websites (METWR, 2024). Most weather stations in Iraq have switched to an automatic meteorological system, and weather data is shared and exchanged worldwide through the World Meteorological Organization (IMOS, 2024). Automated

weather stations for agricultural fields have also been used by some researchers, such as AL-Rawi, (2024a).

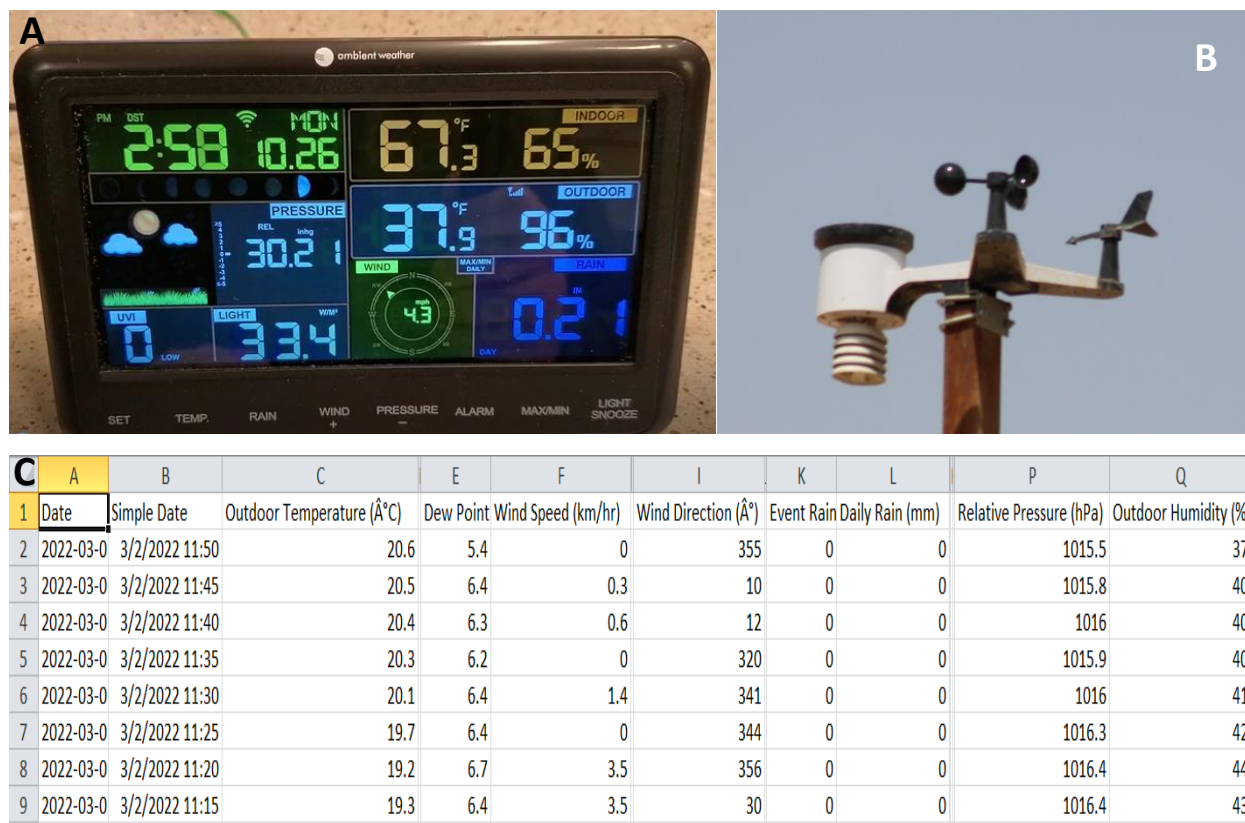
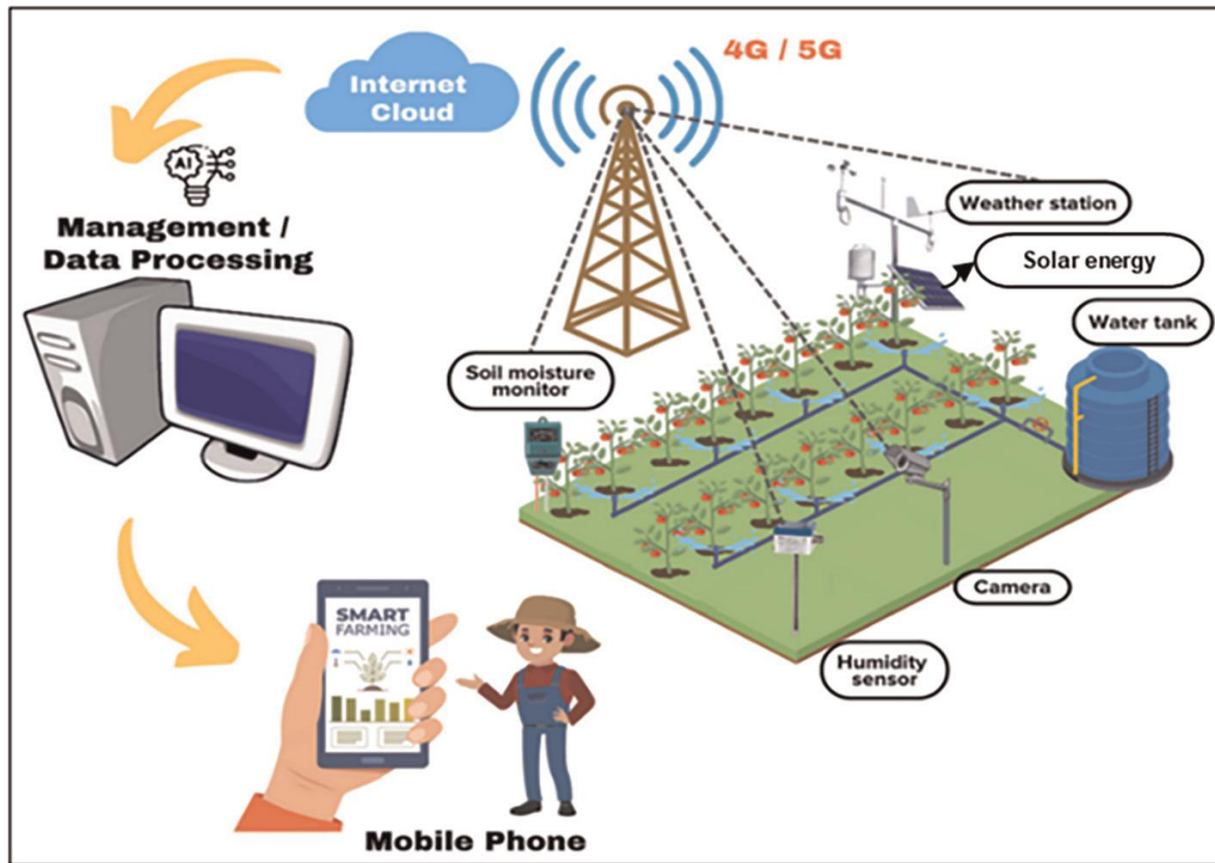


Figure (1): An electronic climate station, B a screen console displaying real-time climate data, C a scheduling file of observed climate data for a full day (24 hours) every 5 minutes. A technique used by (AL-Rawi, 2024a)

Scientific Research and Agricultural Work:

1. Smart Irrigation:

Generally, smart irrigation system (figure) incorporates renewable energy sources (solar or wind), sensor technology, artificial intelligence (AI), machine learning (ML), Internet of Things (IoT)-based decision support systems or smart irrigation solutions, and a mobile application (serving as a user interface) to remotely control and monitor mechanisms to optimize energy and water use in irrigation (Aleem et al., 2024; Hassan, 2023; Pereira et al., 2023) Modern smart irrigation systems rely heavily on a combination of soil moisture and tension sensors, along with data provided by electronic climate station sensors. Various types of sensors are used, including both low-cost and high-cost resistive and capacitive soil moisture sensors (Al-Rawi, 2024b)through the development of an irrigation control to improve the efficiency of the management of the equipment (Kamyshova et al., 2022).



Working scheme of smart irrigation, from (Ali et al., 2023).

Companies specializing in modern irrigation technologies have many notable applications in this field. For example, the American company Valley provides advanced solutions, as follows:

- A. AgSense: A smart irrigation solution is integrated into smart panels. This advanced technology enables remote irrigation management using devices such as a smartphone, tablet, or desktop computer. The AgSense app captures, collects, and transmits data for use in operations. This network is designed to provide unlimited, real-time remote management of anything related to irrigation operations (Valley, 2025a).
- B. Run Time: A calculator eliminates errors from calculations done with paper and pen, and keeps calculation information at all times on the phone (Valley, 2025c).
- C. Valley 365: A comprehensive cloud-based platform for managing the technologies (variable-rate irrigation, scheduling, and insights). Valley 365 provides real-time data whenever and wherever users need it from three key areas within the agricultural ecosystem: equipment, environment, and agronomy. Information is transmitted from field devices, which provide recommendations for potential irrigation amounts, the irrigation plan, variable rate irrigation (VRI) application, and health risk assessments. Users can also check the status of irrigation devices, weather data, and soil moisture levels in real time through smart panels. Access is granted via a smartphone application or personal computer by entering the geographical field location (GBS) (Valley, 2025d).

These smart solutions is related to some smart techniques such as:

1. **Water Level Sensing Technology:** This technology uses ultrasonic sensors to measure water levels in rice fields above and below ground. It allows farmers to check water levels in real time from remote locations. Notifications are triggered when water levels reach high or low points, and the system automatically activates or deactivates the pump based on these water level triggers (Valley, 2024).
2. **Variable Rate Irrigation (VRI)**:** This technique improves water use by controlling the irrigation speed. The field is divided into multiple sectors, allowing for tailored irrigation across each area. A central pivot irrigation system adjusts its speed to achieve the desired application depth in each sector. This speed control is managed through proprietary applications, such as the ICON control panel, which provides control remotely, and the 365 platform, which is an interface for access-class remote management (see Figure 2). Liakos et al., (2015) developed this system by using a soil moisture sensor and tested it to quantify the potential of integrated VRI with advanced irrigation scheduling driven by sensor data. A custom VRI recipe can pulse the control valves of the sprinklers along the center axis zones to ensure the right application depth. It also allows for on-off control in non-irrigated areas of the field. This method is particularly beneficial for rectangular fields with varying soil types and sections that do not require irrigation. As a result, it is often used by research institutions in test fields (Valley, 2024). As a VIR study example, (Agyeman et al., 2023) delineate a three-stage irrigation management zone approach, and a model-based scheduler is proposed to provide VIR schedules for a 26.4-hectare.
3. **Irrigation Scheduling:** This process involves using an advanced management program that offers easy-to-understand recommendations for irrigation. These recommendations are based on scientific data related to soil conditions, crop type, growth stage, and automatically updated weather information. Its implementation requirements include installing an electronic climate station with sensors, including soil moisture (Θ), salinity (EC), and acidity (pH). A smart irrigation schedule is determined after feeding the program information on soil specifications, such as the moisture content at field capacity Θ_{fc} and the permanent wilting point $\Theta_{w.p}$. The schedule information is synchronized with the VRI for implementation. Many researchers studied scheduling in the automation center pivot, such as (Kranz et al., 1992; Peters & Evett, 2008).
4. **Insights Technology:** An artificial intelligence-based technology that uses aerial imagery to detect crop health concerns. This includes early detection of crop health problems and receiving notifications of potential damage to take proper action. It also detects sprayer failures and crop stress caused by weeds(Valley, 2025e).

All these tichniqus are controlled by a smart control panel called ICON (Figure 2), control at the pivot, and control remotely to access the real-time status of the pivot and other inputs (Valley, 2025b).

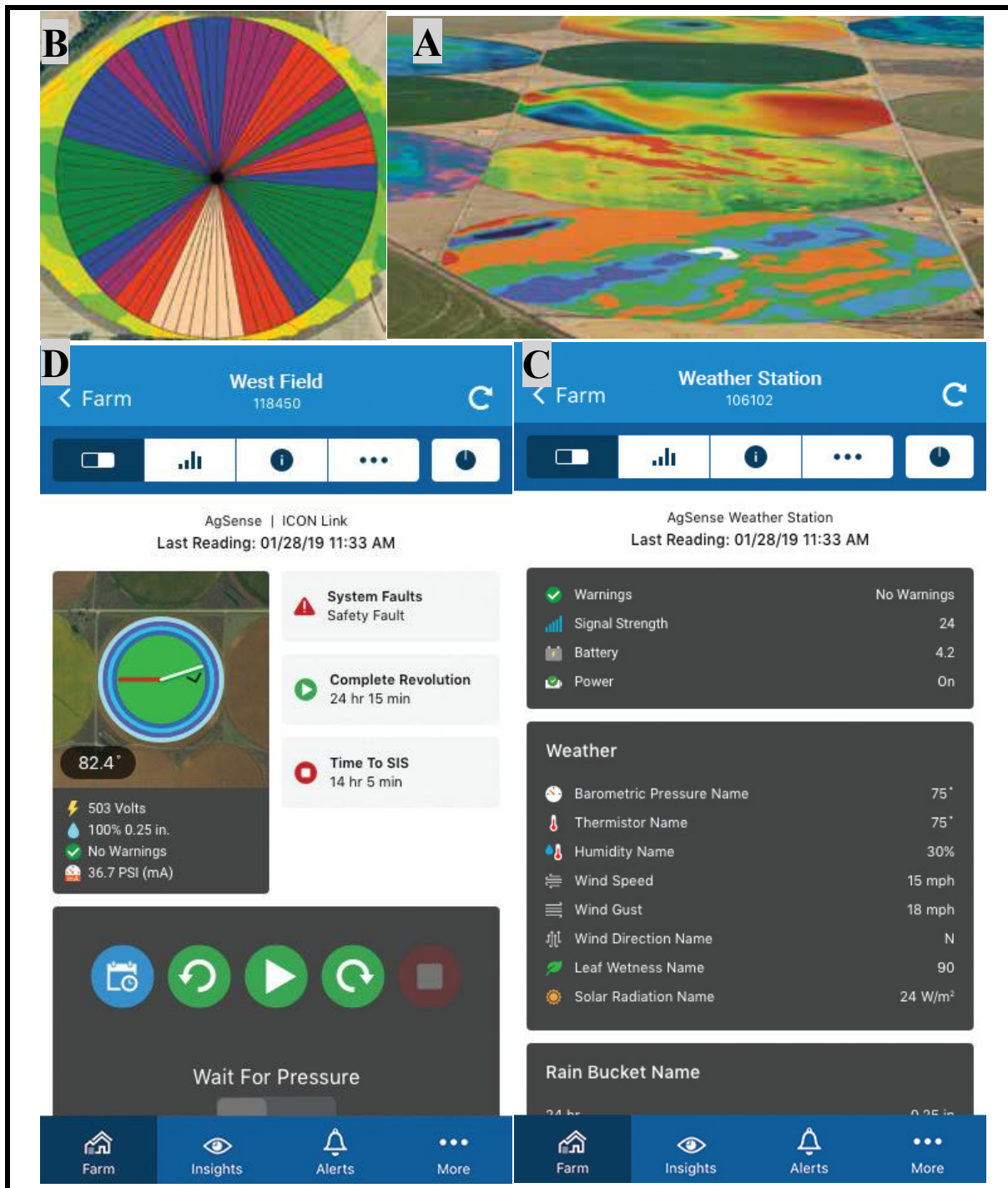


Figure 2: (A) diagram of dividing the field into variable irrigation rates, (B) aerial photographs of irrigation at variable rates, (C) and (D), the dashboard for watching the climate station and the ICON application, respectively, based on Vally Center Pivot Irrigation Technologies.

Scientific Laboratories and IoT Technologies:

In scientific laboratories utilizing IoT technologies, laboratory devices must be "smart." According to Silverio-Fernández et al., (2018) three main features define a smart device: independence,

context-awareness, and connectivity. Independence refers to the device's ability to work without human intervention. Context-awareness means that the device understands its surroundings and includes sensors to watch variables such as temperature and time. The most crucial feature, connectivity, allows the device to access and connect to communication networks for data exchange.

IoT devices use connectivity through the cloud to continuously watch the laboratory environment and equipment, manage inventory, and collect data (Labcompare, 2024). This enhances laboratory workflows and ensures that equipment works smoothly under reliable and safe conditions. There are alarm devices that watch the laboratory environment, sending data and alerting users when conditions fall outside the required specifications. Additionally, there are devices designed to collect both digital and descriptive data about laboratory equipment, which are connected to Laboratory Information Management Systems (LIMS) and Electronic Laboratory Notebooks (ELN).

LIMS is a software system that helps manage laboratory operations by easing access to and preservation of laboratory materials (see Figure 3), operating laboratory tools, and archiving results (Elecetrum Lab, 2010). This system manages all data generated during the laboratory analysis process related to customer samples. This data is used to create the laboratory’s final product: the Certificate of Analysis (COA) (Boyar et al., 2021). On the other hand, the ELN serves as a digital version of a traditional paper notebook, allowing scientists and researchers to record all information related to their experiments within an application on their personal computers. The ELN is the primary recording space for research data and is used to document hypotheses, experiments, analyses, and interpretations of data (Gerlach et al., 2020). Typical uses of LIMS and ELN include managing devices such as incubators, scales, pH meters, and other smart devices that are connected to these systems.


OK	Tool:			
	Emma			
	Responsible department:	Responsible person:	Phone number:	
	Acreo	Magnus Lindberg	632 78 22	
	Full tool name:		Tool ID:	Room:
	Mask aligner MA6/BA6 Karl Suss		524	Gul 3
	General purpose::			
	Mask aligner, principally for backside alignment.			
Instructors:	Dept.:	Email:	Phone number:	
Cecilia Aronsson	Replisaurus	cecilia@replisaurus.com	070-287 71 01	
Helena Strömberg	Acreo	helena.stromberg@acreo.se	632 77 26	
Olof Öberg	Acreo	olof.oberg@acreo.se	632 78 19	
Magnus Lindberg	Acreo	magnus.lindberg@acreo.se	632 78 22	
Restrictions/safety/environment:				
LIMS Info		Booking	Logging	
		Compulsory	Compulsory	
2010-01-08/Per Wehlin Electrum Laboratory				

Figure 3: An example of a label for a laboratory instrument (Mask aligner) reserved through the LIMS system and marked “Booking Compulsory” based on (Elecetrum Lab, 2010).

Common benefits and differences between ELNs and LIMS:

ELNs and LIMS are valuable digital tools that enable researchers and laboratory managers to focus on scientific research rather than expending resources on developing difficult-to-maintain in-house systems. Both offer user-friendly interfaces and can be customized to meet user requirements. They also offer the opportunity to connect to laboratory equipment and other external applications, or to use them on portable digital devices such as tablets and smartphones (SciNote, 2025).

There are several differences between ELNs and LIMS. One key difference is that ELNs are typically designed to store and record unstructured research data (such as experimental data from the R&D phase), while LIMS are designed to store structured, repetitive data based on patterns and templates (such as diagnostic results from a testing lab). This means that electronic laboratory records (ELNs) are more focused on experiments and work efficiently in situations that require flexibility to accommodate changes or record experimental details, such as results, troubleshooting, or unstructured notes. On the other hand, laboratory information management systems (LIMS) focus primarily on samples (storage, labeling, recording, reporting, and authentication), so they operate efficiently in environments characterized by repetitive and consistent activities (SciNote, 2025). An institutional project by (Argento, 2020) showed that the ELN/LIMS platform helps to capture and record data, and helps to make the data to become Findable, Accessible, Interoperable, and Reusable (FAIR), but there is a slow adoption of the ELN by research staff, partly because the ELN is still a work in progress, partly because old working habits are slow to change.

Greenhouse Management:

Wireless Sensor Network (WSN) technology is used in innovative management. A Wireless Sensor Network (WSN) is a set of sensors with wireless interfaces that can communicate with each other and form a network. It works through an electronic application (Yick et al., 2008). It is very small in size to show and watch sensor data distributed on the farm in difficult environments, such as bottles. The WSN typically consists of a MicaZ cup used to measure temperature, light, pressure, and humidity in protected bottles (Akkaş & Sokullu, 2017a).

Furthermore, Internet of Things (IoT) technologies enable the sharing of these measurement data, allowing stakeholders, such as farmers or researchers, to control and watch the greenhouse environment remotely through their cell phones or computers connected to the Internet (see Figure 4).

In the study, (Darmono et al., 2020) using the conditioning system in WSN, by spreading 6 nodes at each point and each node equipped with 3 sensors concluded that the percentage of temperature testing deviation in the greenhouse before using the system increased by 23% while the humidity value also increased by 4%, and the soil moisture parameters by 1.20%. With these results, the observation and conditioning of the greenhouse are getting better and are expected to increase the yield of plants in the greenhouse.

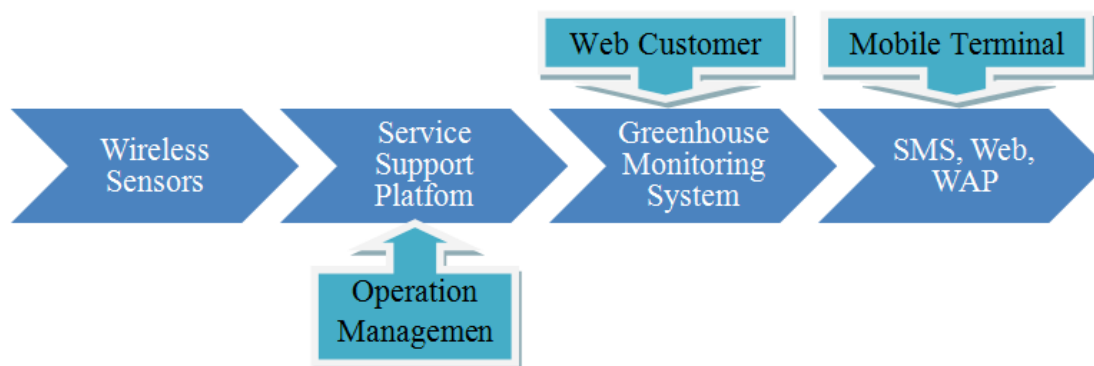


Figure 4: IoT software modules for greenhouses. Quoted from (Akkaş & Sokullu, 2017b)

4 - Animal Production Project Management:

Animal Production Project Management:

The Precision Livestock Farming (PLF) system is an innovative production system approach that can be defined as managing livestock using the principles and technologies of process engineering (Pomar et al., 2019; Wathes et al., 2005), and has been developed in recent decades, aiming to:

- 1 -Improve overall production, while increasing productivity and humanity, through the application of advanced information and communication technologies (ICTs), and the targeted use of clear visibility of output (Banhazi et al., 2012; Chamberlain-Ward, 1998; Cumby & Phillips, 2001) .
- 2 -Objectively documents the productivity of its status.
- 3 -Reduce greenhouse gas emissions to ensure the environmental performance of farms.
- 4 -Facilitate the segmentation of products suitable for commercial marketing and prevent an illegal trade in agricultural products, thus enabling the selection of areas (Banhazi et al., 2012) .
- 5 -The traceability of feed and food (Figure 5) is an essential element of the system (István Komlósi, 2012; Lehr, 2011) .

The Internet of Things (IoT) has entered this ecosystem by integrating digital technologies into PLF, including satellite location data recording, remote sensing, and near-field data collection technologies. It enables an information-based approach to agricultural innovations, improving yields and profits, and provides a new set of tools. This is not entirely new, however, in adopting a "one-to-one" approach. (Lehr, 2011).

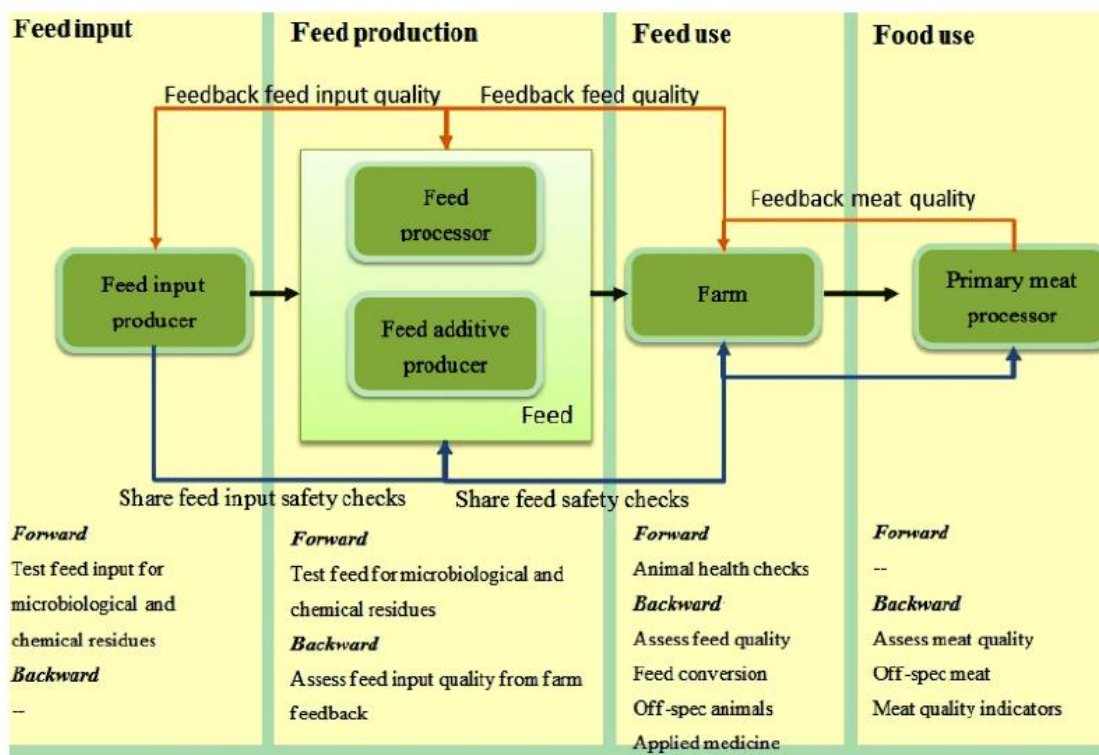


Figure 5: Tracking and links in the PLF system, adapted from (Lehr, 2011)

Lehr, (2011) show that PLF applications can only serve as decision-making support tools for farmers, since automatic decisions for efficient handling and critical health and welfare issues are not feasible at present, while Kleen & Guatteo, (2023) see, it is to be expected that PLF will alter the animal–human relationship and will have a substantial impact on veterinary practice.

Conclusion and Recommendations:

The study concludes that Internet of Things applications are used in many areas of scientific research and agricultural production, some of which are already widely used, while others remain limited in Iraq. Despite the significant benefits offered by the use of these technologies, such as control and document scientific and production data, security alarm and task scheduling which impact the robustness and reliability of scientific research and improve agricultural production, some obstacles limit the transfer of these technologies to practical use, some of which are financial, others related to administrative decisions and planning. The scientific and production centers in Iraq can be able to add this IOT system by developing a practical and organizational framework for these centers by using digital management systems and integrating them into the IoT environment. This process needs to update existing devices and replace them with digital smart devices that are compatible with digital applications. This requires the availability of an uninterrupted internet service.

However, there is hope that these innovative technologies will be adopted and widely implemented shortly.

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