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TECHNOLOGICAL APPLICATIONS FOR SUSTAINABLE AGRICULTURE : A TRINOMIAL

APLICACIONES TECNOLÓGICAS PARA LA AGRICULTURA SOSTENIBLE: UN TRINOMIO

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Abstract: In recent years, technological development has made it possible to implement sustainability-oriented solutions in the agricultural sector, leading to significant improvements. The practical application of information and communication technologies and of blockchain technology in agriculture, gives a deeper digital meaning to agricultural challenges and possibilities. This article addresses the trinomial: technology, agriculture and sustainability. The present research reviews some examples of the application of those technologies in real-world scenarios, as well as their evolution and contribution to agricultural sustainability.

Keywords: agriculture; iot; Edge computing; sustainability; blockchain.

Resumen: En los últimos años, el desarrollo tecnológico ha hecho posible la aplicación de soluciones orientadas a la sostenibilidad en el sector agrícola, lo que ha dado lugar a importantes mejoras. La aplicación práctica de las tecnologías de la información y la comunicación y de la tecnología blockchain en la agricultura, da un sentido digital más profundo a los retos y posibilidades agrícolas. Este artículo aborda el trinomio: tecnología, agricultura y sostenibilidad. La presente investigación revisa algunos ejemplos de la aplicación de dichas tecnologías en escenarios reales, así como su evolución y contribución a la sostenibilidad agrícola.

Palabras clave: agricultura, IoT, Edge computing, sostenibilidad, blockchain.

1 Introduction

Optimal agriculture is fundamental if the human civilization is to continue prospering. This is because farming must meet the basic needs of daily life. The agricultural industry must adapt to the current market, using resources efficiently and respecting the environment. This study reviews different state-of-the art technologies that are being applied on the agricultural market and analyzes the environmental effects of those technologies.

As [10] indicates, the Food and Agriculture Organization of the United Nations estimates that between 20 % and 40 % of world crop production is lost each year due to pests and diseases, despite the application of about two million tons of pesticides. Intelligent devices, such as robots and drones, could allow farmers to reduce agrochemical use through the early detection of crop pests, enabling the accurate application of chemicals or the elimination of pests.

This document is structured as follows: Section 2 describes different state-ofart technologies that are being used in agriculture, Section 3 presents sustainability implications, Section 4 is a discussion on the topic and Section 5 draws conclusions.

2 Technological advances in Agriculture

Thanks to technological advances, farms in developed and developing countries can benefit from the application of low-cost technologies. In this regard, the internet of things (IoT) and, more specifically, the industrial internet of things (IIoT), is presented as a key enabling technology for implementing and monitoring resource management solutions in various scenarios in industry 4.0, including smart agriculture environments [14].

IoT can be used in combination with other technologies such as *cloud computing*, *big data*, *AI*, or *distributed ledger technologies* (e.g. blockchain) to implement solutions that improve the traceability and productivity of industrial processes [18]. However, when trying to transmit data to the cloud, several challenges arise regarding the privacy of the data, power consumption or costs associated with the use of cloud services [2]. In this regard, service providers charge fees based on the amount of data that is transferred, stored and processed in the cloud [16]. By using *edge computing* technologies, it is possible to reduce the volume of traffic transferred between the IoT layer and the cloud [1]. Edge computing offers a potentially manageable model for smart farming integration. As mentioned above, in addition to the importance of transferring data efficiency to the cloud, another very important aspect is the immutability of the data. The use of blockchain technology as an upgrade of electronic agriculture, organically combined with information and communication technologies, means that the benefits of both technologies can be enjoyed at the same time [4].

The increasing demand for food in terms of quality and quantity has increased the need for industrialization and intensification in the agricultural field. Internet of Things (IoT) is a very promising technology that offers many innovative solutions to modernize the agricultural sector. For a clearer contextualization of the following concepts, Figure 1 presents an schema of how they can interact.

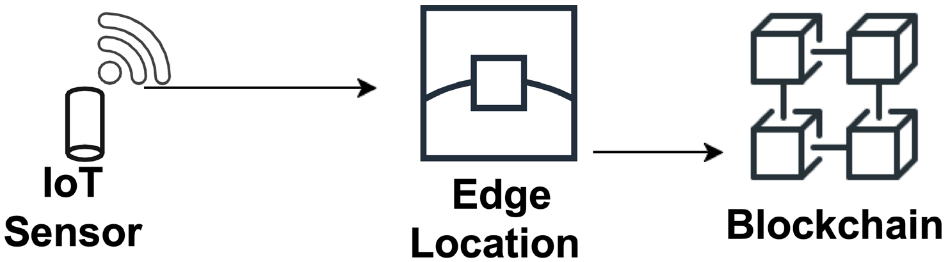

Fig. 1. Interaction diagram.

2.1 IoT

The concept of IoT was coined by a member of the development community of radio frequency identification (RFID) in 2000, and has recently gained more

importance in the real world. This is largely due to the increase in mobile devices, integrated communication and ubiquitous, cloud computing and data analysis [12].

Internet of things (IoT) refers to the general idea of connected things, especially everyday objects which are readable, recognizable localizable, addressable by a detection device and / or controllable via the Internet, regardless of the media. In the literature there are multiple IoT models oriented to the monitoring of the environmental conditions of a farm through a series of deployed sensors. All these models require, for correct operation, robust transmission on which to later be able to develop predictive artificial intelligence models.

IoT offers many solutions for each of its application areas. Some of the most important functions are: management of multiple communication protocols, data processing, information and response in real time, big data storage, security and data privacy [14] or data visualization [5].

However, the implementation of these functions entails a series of challenges that must be solved: the heterogeneity of data sources, security, privacy, latency, real-time response and the use of shared computing resources. While using IoT data ingestion layers can solve the problem of heterogeneity, other issues need to be addressed. One of them is the high volume of data that can be transmitted to the IoT platform by hundreds, thousands or even millions of devices. In this regard, solutions such as the *edge computing* paradigm have emerged in response to the need to reduce the amount of data traffic between the IoT layer and the cloud.

2.2 Edge Computing

Edge computing allows for the execution of machine learning models on the edge of the network, reducing the response time and providing a certain level of service even if the communication with the cloud is interrupted. This is commonplace in scenarios where Internet connectivity is limited (for example, rural agricultural environments) [2].

Different applications of edge computing were reviewed [15] and it was concluded that many applications had a very high potential in the agricultural industry. Moreover, [2] presented a platform oriented to the application of IoT, edge computing, artificial intelligence and blockchain techniques in smart farming environments, through the new global edge computing architecture. It was designed to monitor the status of dairy cattle and feed grain in real time, as well as ensure the traceability and sustainability of the different processes involved in production.

2.3 Blockchain

The emergence of blockchain comes from the latest advances in information and communication technology. This progress has promoted the traditional computeraided industry towards data-driven decision-making. Blockchain is a digital tech-

nology that is helping the smart industry evolve. Some authors see blockchain as an agent of change for the use of technology in agriculture.

When agricultural electronic systems are built with blockchain infrastructure, they are immutable and distributed systems for ledger management, the integrity of agricultural environmental data is safeguarded for those involved in transparent data management.

Although there are many applications based on blockchain in agriculture, their use is not worldwide. China is definitely the leader in the application of blockchain technologies, as evidenced in the reviews conducted in [3] and [17].

Some case studies presented in the literature, such as the one in [8] proposed a blockchain-based fish farm platform to ensure the integrity of agricultural data. In the case presented by [8], the designed platform aims to provide fish farmers with secure storage to preserve large amounts of agricultural data that cannot be manipulated. Various processes on the farm run automatically through the use of the smart contract to reduce the risk of error or tampering.

Some authors examined the impact of blockchain technology on agriculture and the food supply chain, [9] presents existing projects and initiatives underway, and discusses the overall implications, challenges, and potential, with critical insight into the maturity of these projects. Their findings indicate that blockchain is a promising technology towards a transparent food supply chain, with many ongoing initiatives on various food products and food-related issues, but there are still many barriers and challenges hindering its popularity among farmers and systems.

3 Sustainability implications

Sustainable intensification of agricultural systems offers synergistic opportunities for the co-production of agricultural results and natural capital. Efficiency and substitution are steps towards sustainable intensification, but redesigning the system is essential for optimal results as ecological and economic conditions change. Information Technologies can contribute to the transition of agri-food sustainability by increasing the productivity of resources, reducing inefficiencies, reducing management costs and improving coordination of the food chain [6]. Moreover, [11] explored how current social trends in the agri-food system offer new opportunities for pulses, and how simultaneous changes in both production and consumption can facilitate this double transition.

Food sustainability transitions refer to the transformation processes that is needed to move towards sustainable food systems. Digitization is one of the most important ongoing transformation processes in global agriculture and food chains. Crop diversification can improve the sustainability of western agriculture. In particular, legumes can help both agriculture and the food industry to be more environmentally friendly, as they reduce greenhouse gas emissions and help reduce the consumption of meat.

4 Discussion

Regarding agricultural production, the disparity between developed and developing countries is narrowing, as the market is increasingly globalized and more competitive. The Common Agricultural Policy (CAP) [7] provides and manages the resources of the EU budget, providing support to the countries of the European Union (EU), in the form of income to farmers, market orientation and environment. The CAP also regulated the evolution of quotas for agricultural industries. Although quotas have been eliminated, there is great concern among agricultural lobbies about the real effects of quotas over time, as well as their economic impact on a market, over the years. In addition, the challenges facing the European dairy industry are also applicable to dairy farmers around the world: the need to increase resource efficiency, to be more environmentally friendly and to apply the latest technological trends that allow to offer detailed information to the final consumer, while guaranteeing the safety and quality of the final product.

5 Conclusions

The transformation of the agricultural sector is becoming a reality; the technology being used in production is gradually becoming more advanced, as are the challenges faced by producers [13]. CAP's most recent scope of work includes water resources and effective water management. Thanks to the progress of science and technology, the practical application of information and communication technologies and blockchain in agriculture, digital agricultural democratization is possible.

In the coming years, IoT, edge computing and blockchain will play a fundamental role in the development of a more sustainable agriculture. Blockchain is a promising technology and will help us progress towards a transparent food supply chain, with many ongoing initiatives on various food products and foodrelated issues, but there are still many barriers and challenges hampering its increased popularity among farmers and the systems.

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