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REVIEW

Analysis of new technologies implemented in the agricultural sector and their effects on international trade: a literature review

Análisis de la distribución y dimensión de la acuicultura en el Perú: evaluación de especies, áreas y tipos de derecho

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ABSTRACT

Rapid urbanization has led to overexploitation of natural resources, threatening food security globally, seeking to mitigate negative effects agriculture 4.0 helps to mitigate these effects as it integrates sensors and advanced machinery, managing deeper analysis of acquired data, thus promoting sustainable economic development and aiming for green finance. Through a systematic review of the literature, the 50 most cited articles were chosen, which resulted in 4 clusters (precision agriculture, artificial intelligence and robotics in agriculture, blockchain and traceability and general impacts on international trade) where it was found that technology has transformed agriculture, which has led to improved product quality, reduced costs and time in supply chain management, however implementation is complex due to its high costs, on the other hand global warming and lack of water threaten agricultural production, and non-tariff barriers can distort the market for developing countries that depend on agriculture.

Keywords: agriculture; international trade; technology; food safety; sustainability.

RESUMEN

La rápida urbanización ha llevado a que se sobreexploten los recursos naturales, amenazando la seguridad alimentaria a nivel global, buscando mitigar efectos negativos la agricultura 4.0 ayuda a mitigar estos efectos ya que integra sensores y maquinaria avanzada, gestionando análisis más profundos de los datos adquiridos, promoviendo así un desarrollo económico sostenible y apuntando por las finanzas verdes. A través de una revisión sistemática de la literatura se eligieron los 50 artículos más citados, en donde se obtuvo como resultado 4 clústeres (agricultura de precisión, inteligencia artificial y robótica en la agricultura, blockchain y trazabilidad e impactos generales en el comercio internacional) en donde se halló que la tecnología ha transformado la agricultura, lo que ha llevado a una mejora de la calidad de los productos, reducción de costos y tiempo en la gestión de cadena de suministro, sin embargo la implementación es compleja debido a sus altos costos, por otro lado el calentamiento global y la falta de agua amenazan la producción agrícola, además las barreras no arancelarias pueden distorsionar el mercado para países en vía de desarrollo que dependen de la agricultura.

Palabras clave: agricultura; comercio internacional; tecnología; seguridad alimentaria; sostenibilidad

INTRODUCTION

Modern agriculture has faced various challenges due to the growing urbanisation and industrialisation of the global environment, leading to high demand and excessive use of natural resources, directly threatening food security and ecology worldwide (B. Yang et al., 2022). Seeking to bring about positive and precise change is emerging precision agriculture, which incorporates advanced technologies such as information systems and sensors to optimise agricultural production, to move towards the concept of agriculture 4.0, improving the use of inputs while continuing to promote the responsible use of natural resources, to achieve an optimal, healthy and sustainable environment. On the other hand, robotic artificial intelligence has had a significant impact, as it supports more efficient crop management by collecting statistical data, enabling better decision-making. The technologies and new techniques incorporated help mitigate environmental impact by combining traditional agricultural practices and increasing productivity. Blockchain is another tool used to trace agricultural products, and it has gained importance in the market as it provides transparency and security in the supply chain. Although these techniques have had good results, the adoption challenges are complex as they are difficult to implement and their costs are high.

The adoption of innovative practices in the agricultural sector has been crucial to ensuring the sector's economic growth in international trade. This transformation of the agricultural sector towards sustainable innovation is essential to achieving a globalised and equitable world.

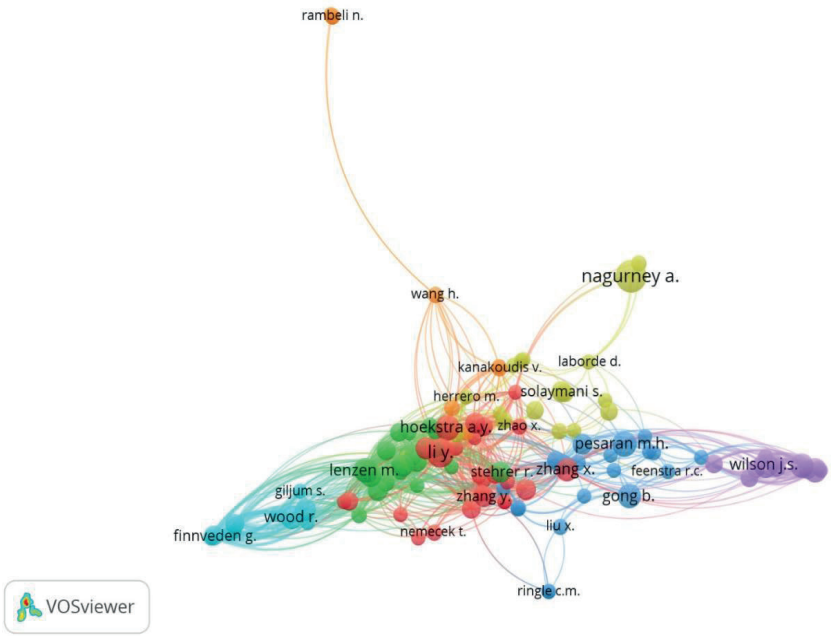
A systematic literature review methodology was used, using the Scopus tool to select the 50 most cited articles to construct the review article. This analysis obtained four key points: precision agriculture, blockchain and traceability, artificial intelligence and robotics in agriculture, and general impacts on international trade. The study of these items revealed that technology has transformed agriculture on a large scale in terms of product quality. It also demonstrated that implementing new technological techniques has optimised supply chain management, improved production, and reduced costs and delivery times, which has led to the entry into new, more global markets. However, although the latest techniques are accurate and promising, their technological implementation is complex due to a lack of knowledge about their application, a lack of digital skills, and their high cost.

METHOD

To achieve the research objective, a systematic review was conducted as an approach for a thorough analysis of the literature. According to Manterola et al. (2023), the literature review involves a broad exploration of the systematisation and selection process, analysing articles in the indexed database. A search was conducted using Scopus, based on the terms 'Agriculture' and 'International trade' under the subject area 'Business, Management and Accounting', including only articles published between 2019 and 2024. As a result, 82 articles were found, to which the following exclusion criterion was applied: Take the first fifty articles with the most citations, from highest to lowest.

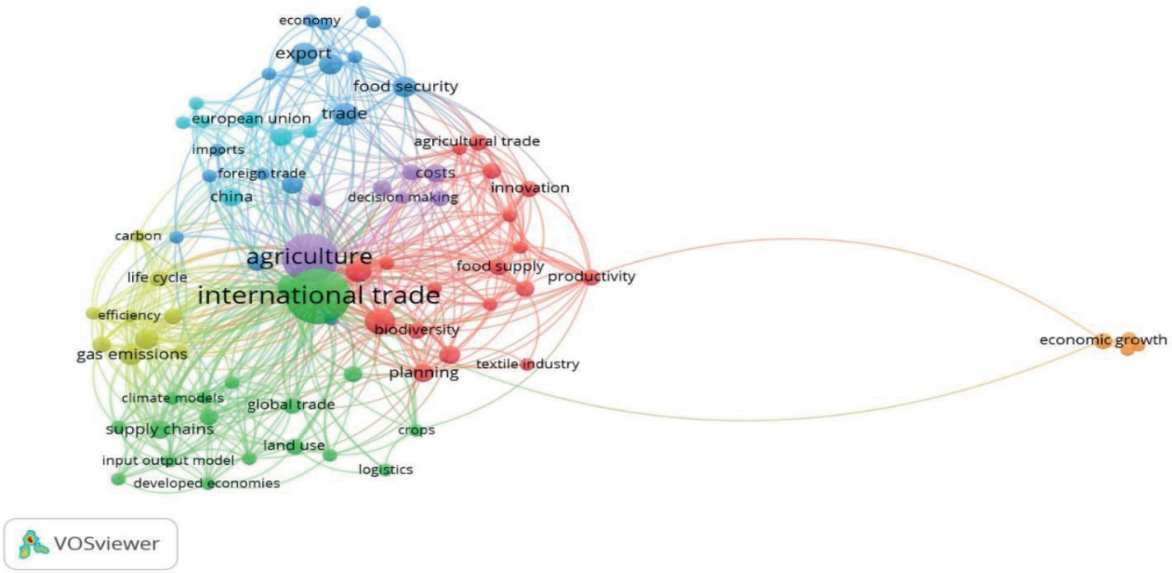
The author network shown in figure 1 was extracted using Vosviewer software, which is necessary for constructing and representing bibliometric networks.

Figure 1.
Network of authors



The authors are arranged in a mesh separated by nodes and colours, where the larger nodes represent the greater number of authors cited, the links symbolise the relationships between their research, and the colours represent the grouping of authors whose research is related, either by a similar area or subject field; for example, Nagumey a. is an essential point in the yellow cluster that is related and connected to different authors such as Laborde d. and Solaymani s. On the other hand, Rambeli N. can be seen as one of the authors with the least connection in the colour groups, which means that his connection is the most isolated in the graph.
The word network shown in figure 2 is obtained using Vosviewer, a software necessary for representing bibliometric networks.

Figure 2.
Word network



A network of colours is reflected, connecting nodes of terms by lines where the node's size relates to the frequency and importance with which they are represented in the research.
The red cluster is mainly centred on agriculture and innovation, productivity, biodiversity, and food supply, linking innovation systems and their impact on food production in trade.
Green and yellow terms are associated with logistics and sustainable land use, the life cycle, gas emissions, and climate change, focusing on environmental protection and reducing the carbon footprint. Blue, purple, and orange terms relate to international trade and relations between countries, including terms such as exports and imports, integrating costs, marketing decisions, and economic growth.
'International trade' and 'agriculture' are the main central terms, despite being the largest nodes, as they are highly connected. They represent topics that are of greater importance in a strong network of interconnections, linking different terms such as productivity, supply chain, sustainability, environmental impact, and food security.

RESULTS

Precision agriculture

Health and food security are important factors in Industry 4.0 trends (Emilio, Torres-Liliana, et al., n.d.). Although B. Yang et al. (2022) assert that rapid urbanisation and industrialisation have led to excessive use of natural resources, seriously threatening global food and ecological security, Mammarella et al. (2022) say that through Industry 4.0, new methods are being applied that adopt sensors, information procedures, and improved machinery to optimise field production in a precise and effective manner.
Therefore, Ayan et al. (2022) assert that greater benefits are obtained by allowing the participation and use of state-of-the-art crop technologies, such as autonomous drone guidance. Green finance, generally considered as financial support for green growth, significantly reduces the greenhouse effect and airborne gas emissions (Zhou et al., 2024). Technological innovation, together with research and development, contributes significantly to the achievement of more environmentally friendly industrial products and processes, without restricting the pursuit of economic development (Alvarado et al., 2021).

According to Thomas et al. (2023), smart agriculture offers the possibility of analysing agricultural data on a scale previously impossible. Researchers argue that combining enriched data and intelligent decision support can optimise agricultural production and profitability while improving sustainability (Cesco et al., 2023). It should be noted that public-private partnerships promote agricultural sustainability, improve food security, and help farmers access technologies (Agarwal et al., 2023).

With this in mind, C. Yang et al. (2024) assert that adopting these new innovative technologies has led to significant advances in the international economy by achieving stability between economic development and sustainability in agriculture and the environment. They are gradually becoming a solid force and driving strategy for ensuring food security, adding value and quality from the beginning to the end of the supply chain (Nordin et al., 2022) and changing the mechanism of our participation, forging results that increase safe and statistically stable agricultural demand, offering a comprehensive and focused structure (Ravi & Rajasekaran, 2023).

Artificial intelligence and robotics in agriculture

According to Armenta-Medina et al. (2020), humans have needed to transform their environment to obtain food since the dawn of time, which led to the development of agriculture. Over the centuries, agriculture has evolved, incorporating new technologies to improve the efficiency of agricultural inputs and increase productivity (Mohammed et al., 2023).

Agriculture is important in global food production and sustainability (Cimino et al., 2024). Although there are some geographical differences, women can be considered the backbone of agri-food systems, representing around 36% of the global agricultural workforce (Perelli et al., 2024). Increasing the efficiency of innovative development in the agro-industrial complex requires the application of modern information technologies for the organisation and management of financial activities, automation, and robotisation (Zghurska et al., 2022).

Consequently, Wen et al. (2020) state that technological application mechanisms in crops are essential tools that involve and employ agricultural technology, mainly encompassing the use of artificial intelligence (AI) and including various mechanisms such as automobiles, robotics, computers, satellites, drones, mobile phones, and software. Therefore, Lin et al. (2025) assert that advances are being adopted to provide broad, resilient, sustainable, and improved production, ensuring food security for all and regular access to good quality food. These intelligences act efficiently in conjunction with the sustainable development of production, mitigating impacts on nature (Y. Zhao et al., 2021). However, the digital divide can limit access to technology in developing countries (Engås et al., 2023).

Similarly, Zech & Schneider (2019) state that the importance of agricultural greenhouse gases (GHG) is a critical issue, as numerous options have been sought to mitigate emissions while considering the optimal use of nutrients. On the other hand, Charykova et al. (2022) say that precision agriculture to reduce the use of synthetic inputs seeks to improve the productivity of products, such as waste reduction or the reduction of GHGs from agricultural inputs (e.g., through the use of renewable energy) to reduce emissions per unit of food produced. Thanks to carbon capture and storage (CCS) technology, which uses carbon-capturing absorbent materials, carbon can be prevented from reaching the atmosphere and having a direct environmental impact (Persson et al., 2019).

Artificial intelligence (AI) has marked the beginning of a paradigm shift in agriculture, particularly in weed management (Vasileiou et al., 2024). AI in this domain extends beyond mere innovation, offering accurate and environmentally friendly weed identification and control solutions, thereby addressing critical agricultural challenges (Latino et al., 2023).

Blockchain and traceability

Blockchain technology has revolutionised supply chain management (Zheng et al., 2023). In particular, in the agricultural sector, blockchain-based traceability has become an essential tool for maintaining the quality and safety of agricultural products (Mangla et al., 2022). However, implementing blockchain technology in agricultural traceability is not widespread due to its high investment cost and complex transactions (Chung & Adriaens, 2024).

According to Narwane et al. (2022), in order to pursue objectives and goals that directly contribute to the transformation of the traditional agricultural sector into an innovative agricultural sector, LOT (Internet of Things) technology processes are being incorporated to enhance the supply chain in terms of object and transport logistics. Similarly, Ancín et al. (2022) assert that IoT technology is geared towards tracking, monitoring, and managing the location and conditions of agricultural goods throughout the supply chain, offering accurate and environmentally friendly solutions. Similarly, R. Sharma et al. (2024) say that various support tools are used, such as communication networks, which help with connectivity and information exchange (Wi-Fi, 5G, Bluetooth), as well as sensors and devices that collect data (humidity, temperature, movement, and status). On the other hand, Latino et al. (2024) state that data management platforms that study the quality control and safety of perishable products and real-time delivery times optimise routes and reduce costs in terms of analysed data. LOT technologies represent a way of optimising agricultural products, bringing benefits such as operational efficiency, reduced errors and waste, and improved sustainability (M. Sharma et al., 2024). However, in logistics, companies often face the challenge of documentation fraud, theft of goods, and discrepancies in the delivery of goods. These challenges can be mitigated

by incorporating blockchain into the logistics sector (Emilio, Torres, et al., n.d.).

2.4 General impacts on international trade

In the agricultural sector, high demand for products is expected, as they are essential for global consumption (H. Zhao et al., 2019). However, Nugroho et al. (2023) state that global warming and water scarcity threaten production. This impacts international trade, affecting the import and export of goods that require large amounts of water for cultivation (An et al., 2021). Liberal trade regimes could improve food productivity if environmental problems, such as adverse climatic conditions affecting agriculture, are addressed (Shuaibu, 2021).

Non-tariff measures as hidden barriers to agricultural trade would not only cause distortions in production and welfare due to the international relocation of activities along the agricultural value chain. However, they would have subsequent consequences for the scale and distribution of carbon emissions from the agri-food system (Mao et al., 2023). It should be noted that Environmental Product Declarations (EPDs) could be required in international trade, which could create a technical barrier to trade for countries with emerging economies (Sampene et al., 2023). Therefore, these countries should assess their readiness to successfully meet this demand (Rocha & Caldeira-Pires, 2019).

Agriculture is unique among other industries because the supply risk, whether due to climate or perishability, challenges vertical coordination between independent agricultural suppliers and commodity buyers (Camanzi et al., 2020). Furthermore, agricultural production is strictly concentrated in certain regions, while others depend mainly on commodity imports (Yuan et al., 2022).

According to Kovalenko et al. (2023), global exports and the share of agri-food products depend on countries' levels of development and specialisation. Consequently, the share of agri-food exports from developed countries is lower than that from developing countries (Surono & Hidayat, 2019). This is because most underdeveloped countries work entirely in agriculture (Chen, 2020). On the other hand, Thom et al. (2024) assert that export bans contribute to higher world market prices, while import bans have the opposite effect.

Globalisation, rapid political transformations, the continuous migration of labour and capital, and contemporary international economic cooperation make it impossible for any country to remain unaffected to some extent when regional conflicts arise (Musarova & Adamkulova, 2023).

According to Abrhám et al. (2021), thanks to the application of these new technologies with a green and safe trade approach for nature and society, several products have been able to enter the international market directly, such as chocolate, rice, soybeans and coffee, which represent a high export rate, as more than 70% of what is produced in the region is exported. These products are produced and delivered quickly and are widely accepted in the global market (Nagurney et al., 2023). In addition, the effectiveness of the transferred technology has a significant impact on the competitiveness of small businesses and their access to international markets (Chege & Wang, 2020).

DISCUSSION

Technological transformation geared towards agriculture 4.0 has proven to be a fundamental resource in the dynamics of optimal agricultural production, food security and environmental sustainability, which is widely agreed upon, as stated by Wen et al. (2020) states that the mechanism of technology application in crops are essential tools that involve and employ agricultural technology, mainly enclosing the use of artificial intelligence (AI) and including various mechanisms such as automobiles, robotics, computers, satellites, drones, mobile phones and software. On the other hand, the author Mangla et al. (2022) emphasises that blockchain has become an essential tool for maintaining the quality and safety of agricultural products, while the author Alvarado et al. (2021) states that technological innovation, together with research and development, contributes significantly to the achievement of more environmentally friendly industrial products and processes, without restricting the pursuit of economic development in an international market. Therefore, we agree with these theories since, thanks to the implementation of new agriculture 4.0 techniques, traditional agriculture has been transformed into smart agriculture, giving way to new structures that enable environmental sustainability and optimise the supply chain, allowing products to reach the global market with greater awareness of environmental care.

CONCLUSIONS

Due to global population growth, there is an increased demand for water and food, putting global food and ecological security at risk. Technological innovations such as Industry 4.0 and artificial intelligence can optimise agricultural production and improve sustainability. Public-private partnerships are key to facilitating access to these advanced technologies and promoting sustainable agricultural practices. It should be noted that automation and blockchain are transforming the agricultural supply chain, but face economic obstacles; green finance supports initiatives that reduce greenhouse gas emissions, thus promoting sustainable economic development and international trade. These also present challenges, as inequalities in agri-food exports reflect the development gap between countries, where nations that depend on the agricultural sector are mostly developing countries. In addition, climate change exacerbates these situations by influencing global food market prices, affecting exports and imports. However, emerging precision agriculture, supported by advanced technologies, offers innovative solutions to optimise

agricultural production, reduce environmental impact, and improve product traceability. These advances have transformed agriculture into a more efficient model and an innovative, sustainable, and globally competitive form of agriculture. Although its implementation is critical and significant, adopting these technologies faces significant barriers, such as complexity in implementation, lack of training, and high associated costs. However, despite the challenges it faces, integrating these innovations is essential to ensure the economic growth of the agricultural sector and its adaptation to the globalised context, promoting more efficient and sustainable international trade with the environment.

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