Opportunities and challenges of artificial intelligence in agriculture: Some brief reflections

Oportunidades y desafíos de la inteligencia artificial en la agricultura: algunas reflexiones breves

In recent years, agriculture sector has suffered significant transformation driven by the development of emerging technologies that form the basis approach known as Agriculture 4.0 (Alam *et al*., 2023). This new agricultural revolution is characterized by the integration of advanced technologies, such as the Internet of Things (IoT), robotics, Big Data, programming and computing, cloud computing, artificial intelligence (AI), among others (Erazo-Mesa *et al*., 2022). In this context, AI plays a crucial role by enabling the integration of these tools to efficiently analyze large volumes of data generated from traditional monitoring methods, proximal and remote sensors, and various platforms for plants, climate, soil, pest populations, and beneficial organism phenotyping.

AI facilitates evidence-based decision-making, optimizing resource use and enhancing productivity, competitiveness, and sustainability in agriculture. AI-based systems can integrate historical and real-time data to develop predictive models that assist farmers in planning their activities. For instance, AI algorithms can generate various innovative applications, such as comprehensive crop monitoring, detection of nutritional deficiencies and pests in plants, assessment of nutrient and soil moisture concentration, harvest forecasting, yield prediction, climate and irrigation forecasting, among others (Erazo-Mesa *et al*., 2022). Additionally, AI-equipped agricultural robots can perform repetitive tasks like planting, weeding, and harvesting with higher precision and efficiency than traditional methods (Wakchaure *et al*., 2023). Additionally, in the commercialization sector, AI can help predict market demand and agricultural product prices, enabling farmers to make informed decisions about when to harvest and sell their products to maximize profits. Furthermore, AI-based e-commerce platforms can connect producers with consumers, facilitating access to new markets and increasing the competitiveness of small-scale farmers (Junhui *et al*., 2021).

Despite its numerous applications and potential benefits, the implementation of AI in agriculture faces several challenges that need to be overcome to ensure its success and sustainability. One of the main challenges is the quality of the data used to train AI models (Rodríguez-Almonacid *et al*., 2023). In many cases, agricultural data is heterogeneous, incomplete, or of low quality, which can affect the accuracy and reliability of predictive models. It is crucial to develop robust methods for data collection, cleaning, and standardization to generate reliable information for decision-making (Rodríguez-Almonacid *et al*., 2023). Additionally, ensuring the reproducibility and transparency of AI models is essential. Often, AI algorithms function as "black boxes," making it difficult to understand how decisions are made (Hu *et al*., 2023). There is also a need to adapt AI solutions to real field conditions, which are often more complex and diverse, involving multiple sources of variation.

Moreover, the applicability of AI in small-scale production systems, particularly in multicultural and economically diverse contexts, represents another significant challenge (Erazo-Mesa *et al*., 2022). In many developing countries, small-scale farmers lack the financial resources or access to advanced technologies needed to implement AI-based solutions (Alam *et al*., 2023). There is also a knowledge gap regarding the use and benefits of these technologies, limiting their adoption. This highlights the need to design accessible, affordable, and user-friendly AI tools (Erazo-Mesa *et al*., 2022). Furthermore, to fully realize AI's potential in agriculture, widespread adoption across value chains is necessary, involving not only the development of accessible technologies but also the training of farmers, companies, technical assistants, and students in their use, along with the creation of public policies supporting the adoption of digital technologies in the agricultural sector (Cáceres-Zambrano *et al*., 2022). These programs should focus on demonstrating the benefits of AI-based solutions

and providing the skills necessary for their implementation. Additionally, the development of open-source and low-cost software platforms can facilitate access to AI tools for small-scale farmers, helping reduce economic and technical barriers to adoption.

Undoubtedly, we are observing a significant technological revolution where AI plays a essential role in human history, and the agricultural sector is no exception. This invites us to harness its vast potential to enhance multiple processes and provide more decision-making elements, promoting the correct, responsible, and honest use of AI. Additionally, to fully capitalize on these opportunities, several challenges must be addressed, such as data quality, model transparency, and applicability in different production contexts. Through overcoming these multiple challenges, AI can become a key tool to address the agricultural sector's challenges and enhance its long-term competitiveness and sustainability, particularly in the changing environments associated with variability and climate change.

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