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EDITED BY
Carlo Ingrao,
University of Bari Aldo Moro, Italy

REVIEWED BY
Mahak Sharma,
Birla Institute of Management Technology, India

*CORRESPONDENCE
Roosevelt Fabiano Moraes da Silva
✉ roosevelt.silva@ifms.edu.br

†These authors have contributed equally to this work and share first authorship

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Digital transformation for improving sustainable value of products and services from agri-food systems

Roosevelt Fabiano Moraes da Silva[1,2,3*†], Matheus Papa[1,2†], Ivan Bergier[1,2,4†], Stanley Robson Medeiros de Oliveira[1,2], Sergio Aparecido Braga da Cruz[1], Luciana Alvim Santos Romani[1] and Silvia Maria Fonseca Silveira Massruhá[1,2]

[1]Empresa Brasileira de Pesquisa Agropecuária – Embrapa Agricultura Digital, Campinas, SP, Brazil, [2]Faculdade de Engenharia Agrícola – FEAGRI, Universidade de Campinas – Unicamp, Campinas, SP, Brazil, [3]Instituto Federal de Educação Ciência e Tecnologia do Mato Grosso do Sul – IFMS, Corumbá, MS, Brazil, [4]Empresa Brasileira de Pesquisa Agropecuária – Embrapa Pantanal, Corumbá, MS, Brazil

Value is routinely concentrated at the final links of food production chains as a consequence of market failures or asymmetries that distribute wealth unevenly in agri-food supply systems. Otherwise, for products with a geographic origin, the share can be more equitably distributed by adding environmental, sociocultural or technological values to products associated with sustainable models. Protecting a geographic indication (GI) of value-added products requires complex collective rules of *sui generis* systems, certified trademarks or business practices, including the approval of protocols or even unfair protection suitlaws. These rules are created on multilevel legislations gathering intrinsic cultural, historical and economic features. As a result, GI schemes are typically costly thus preventing access of general smallholders in product-valued chains. Digital technologies like mobile applications have a promising role in minimizing these limitations along food production chains, from pre-production to production and post-production. The pervasive spread of mobile devices with useful built-in sensors can be therefore a major consequence of the digital transformation in agriculture by means of intuitive applications combined with high-level technologies such as cloud/edge computing and Application Programming Interfaces (APIs). In this article, we present a new perspective on the digital transformation of the agri-food sector that may fasten smallholders' inclusion and access in market ecosystems of value-added products with GI. Such perspective demands the understanding of stakeholders networks for customizing mobile applications for digital authentication of product GI. The approach can foster new compliance schemes as those embedded in Environmental, Social and Governance (ESG) market initiatives.

KEYWORDS

digital inclusion, data accessibility, ESG, geographic indication, traceability

Introduction

The world's need for food has been growing annually, which demands innovation to increase the sustainability of chains of food production, distribution and consumption (Opara, 2003), in consonance with the United Nations Sustainable Development Goals—SGD (Hák et al., 2016). Therefore, major stakeholders in the agri-food sectors (producers, industries, technology, and business companies) have been encouraged to proactively seek for sustainable and transparent food delivery to people (Agnusdei and Coluccia, 2022).

At the same time, the agri-food sector is currently experiencing large-scale crises due to climate change and natural resources depletion (Brown et al., 2015; McGreevy et al., 2022), which is challenging those responsible for sustainably feeding a growing world population (Klerkx and Rose, 2020). Currently, our ability to map agribusiness through massive amounts of data, satellite imagery or unmanned aerial vehicles has powerful implications for public policy and business strategies, so the agri-food sector can, in principle, trace food origins and processing (Opara, 2003). Hence, making agri-food markets sustainable and competitive from small to large players is a big challenge because new digital technologies and production processes emerge every day, integrating stakeholders in more or less centralized topologies, which can accentuate or attenuate information failure (asymmetries) in production networks (Chen et al., 2022).

Figure 1 depicts the interconnections of the following sections highlighting the new perspectives on the digital transformation in the agri-food sector that may fasten smallholders' inclusion in market ecosystems by adding digital value to rural products.

The ease of access of smallholders to mobile applications potentially increases "glocal" (Svensson, 2001; Deblonde, 2015) economic, environmental and sociocultural values for rural products and services, particularly those assisted by protocols aiming at mitigating market asymmetries. In addition, digital transformation can provide organized data and metadata for public and private audits and compliance, which can also be interesting for academic research and commercial innovation aimed at studying and improving the sustainability of products and services with "glocal" values.

Market asymmetries in food production systems

A valuable resource in business is information, essential for the pursuit of the main goals of business transactions and necessary for collaboration and the elimination of inefficiencies. Despite its importance, many companies do not want or cannot share confidential data that could be beneficial to all links in production chains and regulating institutions (Michalski et al., 2018). Thus, market asymmetries occur in a network when one of the parties involved in the business has preferential access to information (Ullah et al., 2020), thereby acquiring advantages from better fitness among the network nodes (Perera et al., 2017). There are many aspects that influence market asymmetries, such as private information about demands, costs, quality and even barriers not evident in the whole system (Vosooghidizaji et al., 2020). That provides new research opportunities to develop responsible digital innovation (Deblonde, 2015) with different approaches and mechanisms to reduce these symmetries and maximize the access and distribution of information in agribusiness network systems.

As with other businesses, agri-food markets evolve in such a way that fitness advantages (Bianconi and Barabási, 2001; Perera et al., 2017) inherently tend to lead to asymmetries in specific linkages that affect the global food system as a whole. Therefore, in connection with many SDG (Hák et al., 2016), overcoming these asymmetries by bringing together and including marginalized smallholders in large market networks with socio-environmental responsibility emerges as a major challenge for the sustainability of current and future generations (Yatsenko et al., 2019; McGreevy et al., 2022). The availability of authenticated and up-to-date information about market operations is at the core of a product efficiency system. For agri-food market chains, the higher self-consciousness of these systems increase the level of food reliability, the trust in network intermediation, and the compliance with sustainability standards. Nonetheless, small and medium-sized rural producers, especially in emerging economies, rarely seek to engage in such systems particularly due to large complexity and high costs of authentication and certification services, which result in a feedback loop that reinforces market failures and asymmetries (Sun and Wang, 2019; Chen et al., 2022). Information digitization and the use of accessible and emerging digital technologies could reduce the aforementioned market failures, making the distribution of information and value more equitable for sustainable production models such as Environmental, Social and Governance (ESG) financial initiatives. In particular, reputation and insurance effects are important mechanisms through which ESG performance can influence stock prices. In fact, ESG effects are considerably pronounced among firms with low human capital and poor image and in high-impact regions (Li et al., 2022).

Under these spotlights, the emergence of opportunities with political and economic will for innovation in ESG business models seems reasonable. In this article, we focus on the perspective of the most promising digital solution that can facilitate marginalized farmer's access to Geographical Indication (GI) protocols as an alternative to minimize asymmetries in food markets with a focus on SGD 1, 2, 8, 9, 10, 12, and 17 (Hák et al., 2016).

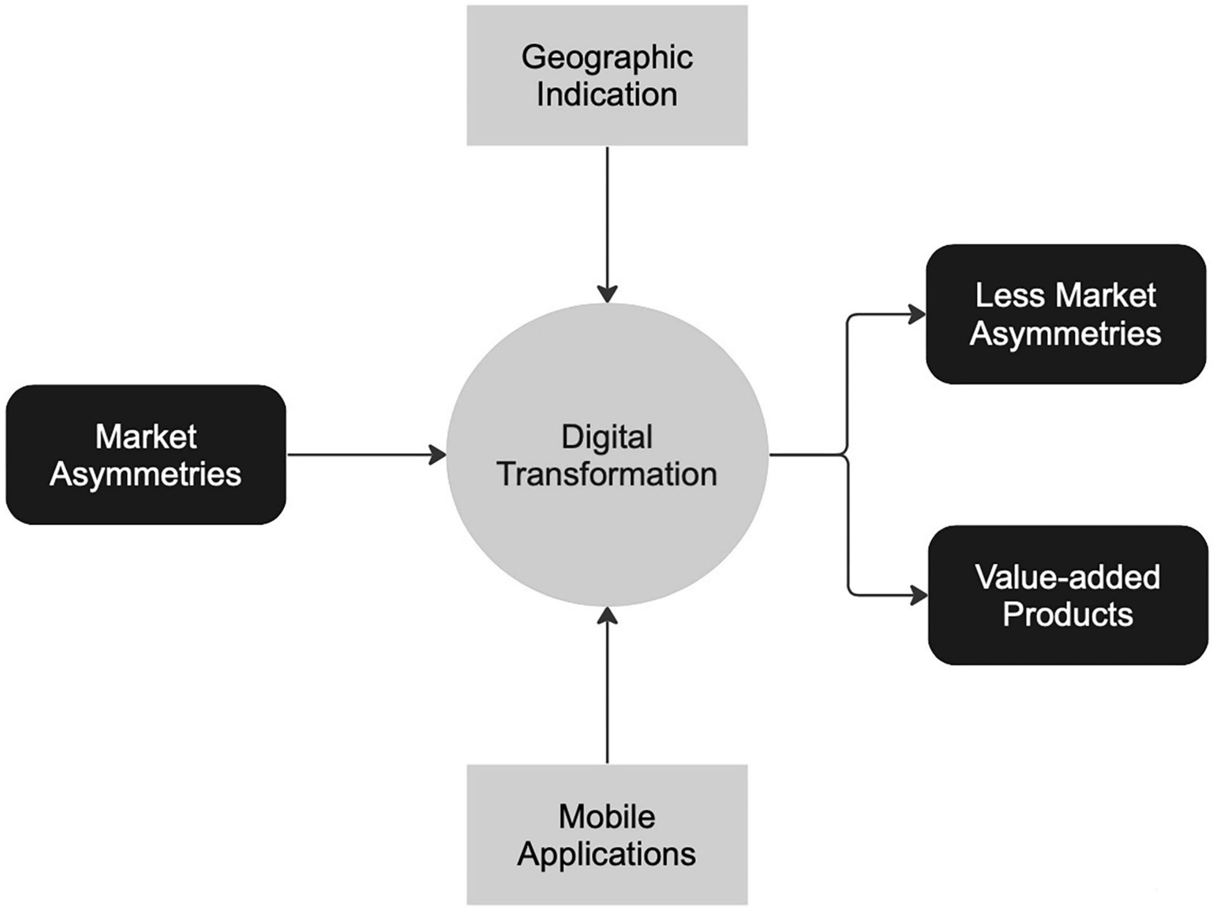

FIGURE 1
Flowchart of sections interconnections.

World system of GI

A GI is an intellectual property mechanism that can be applied to both products and services, characterized by the place of origin where they were collected, produced or manufactured, which must involve elements of environmental, historical specificities, and sociocultural aspects of these places (Medeiros et al., 2016). In general, GI is currently seen and conceived as a protection system, a marketing tool, a rural development device and a means of conservation or preservation of the Earth's natural capital (Chen, 2021).

The use and protection of a GI is not nevertheless a simple task, whether for a value-added product or service, as it requires those involved to comply with complex collective rules of *sui generis* systems, certified trademarks and business practices. This complex system must also include compliance with specific protocols, environmental protection laws, as well as national and international (multilevel) legislations addressing cultural, historical and economic features that are important and intrinsic to the process. With such bureaucratic and complicated processes, GI schemes often end up as expensive as complicated to attend, which make it difficult to access chains of value-added products and services duly indicated by most smallholders.

Simplified digital GI for smallholders to minimize market asymmetries

Food and other rural products registered with a digital GI have emerging implications such as the development of gastronomy-oriented tourism, which positively affects other economic gears (Pamukçu et al., 2021). For instance, consumers of the Italian eucalyptus honey consider the GI an important factor for sustaining the product consumption (Palmieri et al., 2022). In general, members of the European Community are the most interested in protecting GI assets. The Brazilian GI is in a process of expansion and consolidation, indicating an economic perspective for typical products and services of particular locations or regions that preserve traditions and cultural specificities (Gonçalves et al., 2019). Actually, in Brazil there are

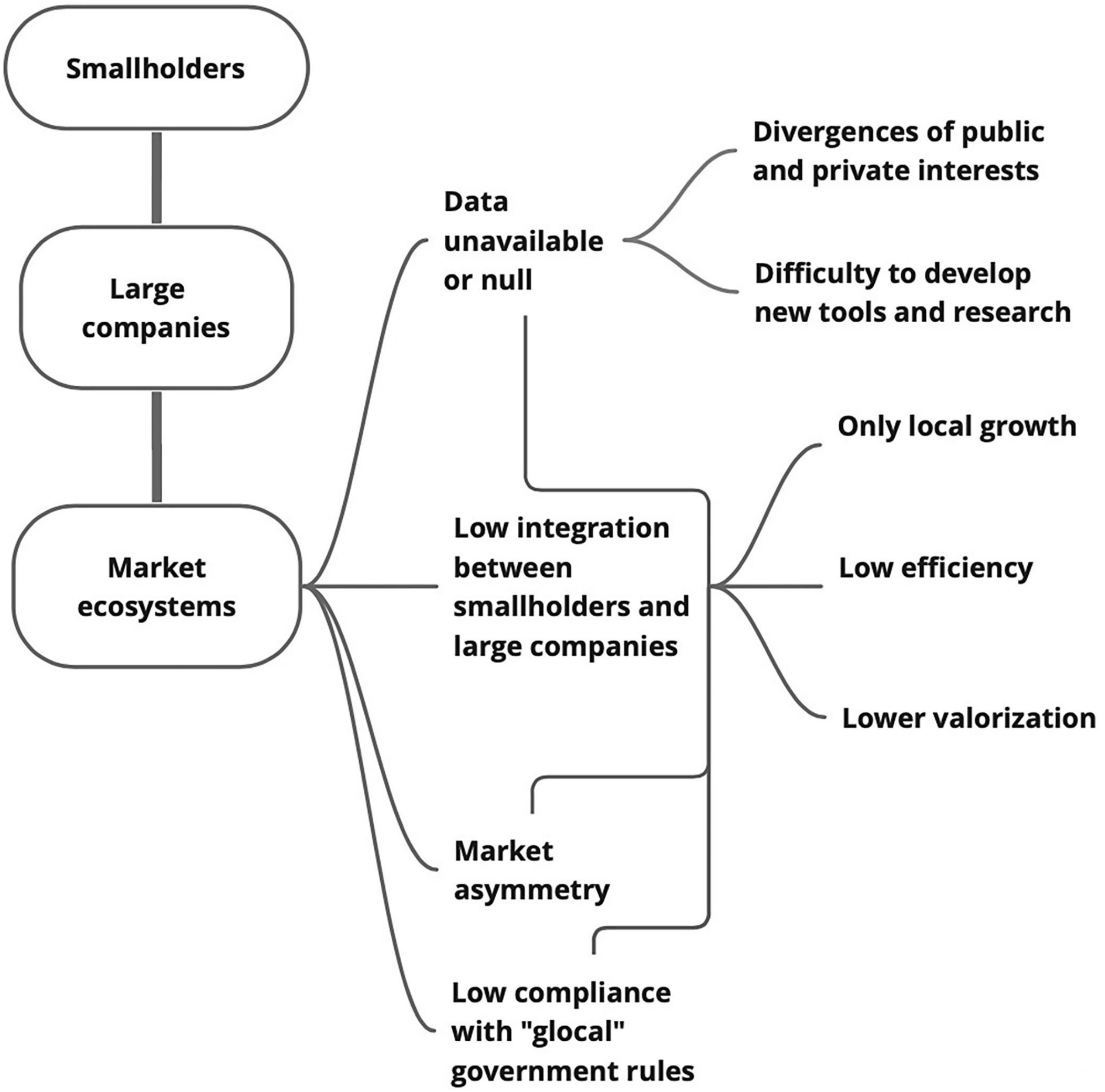

FIGURE 2
Mental map of current smallholders access to the market ecosystem.

several examples of GI as shown by the Ministry of Agriculture, Livestock and Food Supply,[1] with nine international and nearly 70 national GI registers.

The widespread adoption of information technology and communication in protected GI of products and services, associated with ESG protocols, is a promising future for reducing asymmetries in agri-food markets, therefore creating suitable digital cyberspaces for long-term sustainable development. In turn, the amplification of cyberspaces potentially increases the fitness (Bianconi and Barabási, 2001; Perera et al., 2017) of smallholder nodes in real national and international agri-food network systems (Sgroi, 2021).

Therefore, this perspective article conjectures that public policies that ensure broad access to easy, intuitive, and low-cost digital technologies to smallholders, should become commonplace (Deblonde, 2015). Particularly those technologies based on mobile (smartphone) applications and Application Program Interfaces (APIs), GI initiatives, conforming to ESG initiatives for rural products and services. These are current

1 https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/indicacao-geografica/listaigs

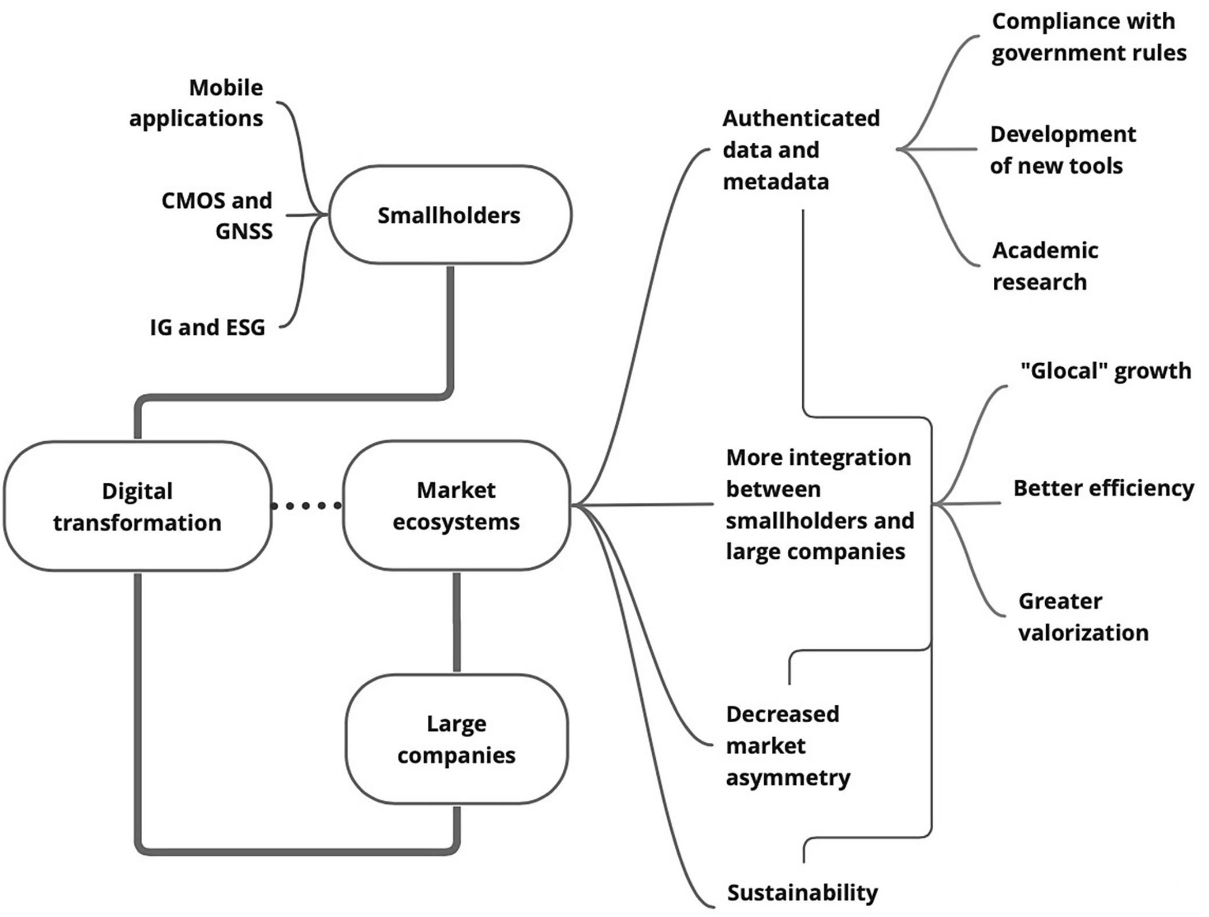

FIGURE 3
Mental map of smallholders access to the market ecosystem with digital transformation.

demands in line with global markets and people moving toward rational consumption of products and services (Li et al., 2022; O'Hearn et al., 2022; Palmieri et al., 2022).

Discussion

Smallholders with no access to digital technology have problems in complying with protocols that potentially add "glocal" value for their products and services. On the other hand, that makes it difficult for large companies (the network hubs) to access and share market value in the market ecosystems of smallholders. The mental map in Figure 2 summarizes these issues arising from the lack of digital technology of information and communication for improving market dynamics.

The technology embedded in mobile devices is here envisaged as a major driver of the agri-food digital transformation. Information and communication technology works toward a greater integration between producers and large companies, as shown in Figure 3, helping in the growth, efficiency and valorization of products and services with the digital certification of origins in rural areas (França et al., 2020).

Currently, much of the satellite-based technologies, such as CMOS and GNSS sensors (GPS/GLONASS/GALILEO/COMPASS), are incorporated into smartphones, thus accessible and useful in everyday life of people. A clear example of digital disruption induced by the massive use of sensors embedded in smartphones can be seen in the transportation sector (Heiskala et al., 2016). Similarly, digital applications development for mobile devices in the agri-food sector might be the triggering of a digital transformation that maximizes national and international agri-food systems performances looking at "glocal" sustainability.

Digital transformation is primarily responsible for a drastic reduction in transaction costs by shortening the mean pathlength among network nodes in the market ecosystems (dotted line in Figure 3), therefore strengthening trustful ties between node stakeholders, and for an enhancement of compliance with environmental and sociocultural values, paving the way for a convergence between collective and private interests. In the future, the main link between both smallholders and large companies to the market ecosystems may consolidate as the dotted line in Figure 3 *via* digital transformation.

The key elements of the digital transformation for the success of initiatives that seek to combine IG and ESG in the agri-food sector are associated with the acquisition of authenticated digital data and metadata from smartphones and data accessibility *via* APIs. Two examples of Brazilian initiatives are presented in Romani et al. (2020) and Bergier et al. (2021). Both innovations rely on making public and private accesses of agri-food data and metadata *via* API, namely the AgroAPI[2] platform, an initiative of the Brazilian Agricultural Research Corporation and partners.

The development of new tools and the analysis of agri-food networks depend on data that are often not collected or publicly available (Valerio et al., 2020). AgroAPI is an API platform for accessing data, information and models in order to add value to the agricultural ecosystem. A variety of applications (apps and web systems) can be developed from the APIs available in AgroAPI, which provide decision support to farmers. The platform contributes to expanding the digital transformation in the field, strengthening the principles of Digital Agriculture (Romani et al., 2020).

Future perspectives

Digital transformation is a one-way route to uncover currently hidden innovations that can promote the integration of ESG and GI of rural products and services but can also open new frontiers to the study and analysis of complex agri-food networks. For instance, cloud/edge computing and API can be integrated in blockchain (Yano et al., 2020) and artificial intelligence (Patrício and Rieder, 2018) applications. As a result, digital transformation in the agri-food sector, and the associated gains of scientific knowledge on these changes, can substantially contribute to the elaboration of useful guidelines for public policies and for decision-making to the fair and responsible trade in agri-food systems.

2 https://www.agroapi.cnptia.embrapa.br/portal/

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

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