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RESEARCH ARTICLE

Distinctive signs as an alternative for the revitalization of the productive system of ocañera onion (*Allium cepa* L.): An analysis of scientific trends

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Abstract

The current context of agribusiness is framed by three major drivers: business models based on bioeconomy and circular economy; mechanisms that ensure quality, safety, and traceability throughout the supply chain; and aspects of the Trade-Related Intellectual Property Rights (TRIPS) agreement. The latter has become a differential factor for both comparative and competitive advantage and is recognized as a potential enabler or constraint for the positioning of primary, minimally processed, and transformed agricultural products. In the case of Ocañera red onion as a primary product, access to distinctive signs covered by the TRIPS agreement, such as denomination of origin or geographical indication, would benefit the promotion of its cultivation, protect trade against homologous varieties from neighboring countries introduced without restriction, and facilitate the promotion of characteristics related to its bioactive and functional components beyond organoleptic properties. For this research, a methodological design based on mixed methods of scientometrics, systematic literature review, and qualitative meta-analysis was implemented, aimed at identifying research trends in distinctive signs for primary agricultural products. From these trends and focusing on specific information about vegetables, enabling and restrictive factors related to distinctive signs were identified. These factors were used to analyze homologous cases of distinctive signs reported for primary agricultural products of the Allium genus. Finally, key factors were classified into five categories related to regulations, product added value characteristics, territory specificities, available technologies for origin and quality assessment, and market dynamics and merged in a five-step route to undertake a certification process for distinctive signs for Ocañera red onion.

Keywords: Geographical indication; terroir; designation of origin; added value; intellectual property; scientific surveillance.

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1. Introduction

The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) significantly influences products generated within agri-food systems, particularly horticultural products such as alliums (species of the *Allium* genus) including onions and garlic. These agreements primarily focus on the protection of plant varieties to encourage innovation in the development of planting materials and genetic improvement processes (Cullet, 2001). Consequently, TRIPS agreements affect aspects related to the economic and environmental management of horticulture-based agri-food systems (Brooks, 2014), not only considering the importance of the biophysical characteristics of the space where agricultural production units (terroir) are located (Meloni & Swinnen, 2018), but also the specific traits these impart to the primary product, especially those related to its nutritional and functional composition (Farinha et al., 2023).

Currently geographical indications comprise the uprising of regional agreements and arrangements, the empowerment of collective uses and the sustainability focus (Li et al., 2025).

In the specific case of alliums, interest in their bioactive compounds primarily stems from their potential uses in traditional and biological medicine (Fredotović & Puizina, 2019), as well as how TRIPS agreements promote the study of genetic diversity within Allium species (Dolatyari et al., 2018, 2023) with the goal of identifying promising varieties with potential for disease prevention, such as cancer, cardiovascular conditions, and other public health concerns (Rocchetti et al., 2022; Stajner & Szöllosi

Varga, 2003); as well as their antimicrobial properties (Kyung, 2012; Najjaa et al., 2011).

In Colombia, the importance of allium crops, particularly bulb onions (*Allium cepa*), and other products included in the country's horticultural food basket, is subject to the dynamics of the local market (availability in volume, quality, and price) and international trade factors, considering export potential, import substitution, and the entry of substitute products priced below the cost of domestic production (Chirivi-Moreno, 2023). Similarly, factors related to the management of production units and specific requirements of production zones can influence access to TRIPS benefits, such as: i) excessive use of chemical inputs for onion cultivation (Gómez Benítez et al., 2022); ii) varying irrigation regimes to optimize water use, which can significantly improve onion yields (Terán-Chaves et al., 2023); iii) efficient resource management and the adoption of technology to enhance profitability (Cely-Reyes et al., 2020); and iv) management practices that reduce environmental and health risks associated with pesticide use (Jangir et al., 2023).

The cultivation of red Ocaña onion is considered one of the most representative products of the city of Ocaña, having been grown for over 100 years. It is not only deeply rooted in the local economy but also part of the cultural heritage of this region (Sánchez, 2016). However, according to Colombia's Ministry of Agriculture and Rural Development, the production area has decreased over the past 10 years mainly due to: i) traditional practices of managing planting material (seeds) through asexual propagation without selection techniques or breeding methods; ii) high susceptibility to pathogens (fungi, bacteria, and viruses); iii) limited in situ and ex situ conservation of promising materials to create a reference collection; and iv) absence of territorial production models for this production system. Although the traditional production system is highly dependent on input management strategies for soil management, irrigation, and pest and disease control (Rosero-Alpala et al., 2024), research advances have been made to support, through scientific and technological knowledge, the potential of the species to achieve a distinctive sign, particularly in the search for promising varieties such as the hybrid "Rosada Milenio F1" (Pacheco-Carrascal & Granadillo-Cuello, 2017); evaluation of the antioxidant capacity of red onion extracts (Meyer-Torres et al., 2010); and scientific evidence of the health benefits of these types of onions due to their flavonoid content, which has anticancer, antibiotic, antiasthma, antithrombotic, and antiplatelet potential (Pérez-Gregorio et al., 2010).

Thus, the aim of this research was to conduct a comprehensive analysis of the available scientific knowledge related to distinctive signs of origin and geographical indication for primary horticultural products to design a route to undertake a certification process for Ocañera red onion.

2. Methodology

The methodological design developed is considered tailored made, as it links tools, methods, methodologies, and models according to the identified problem, facilitating the development of a specific research pathway. This tailored approach addresses the need for differential mechanisms for primary products of agricultural production systems (distinctive signs or differential signs) that: 1) enable access to differentiated national and international markets; 2) create a distinction from homologous or substitute products that enter the market through certified and non-certified imports; 3) highlight research, development, and innovation efforts aimed at improving product quality and safety, the efficiency of production system activities, and the practices of peasant, family, ethnic, and community agriculture (ACFEC); and 4) promote the structuring of local agribusinesses that connect with global agri-food chains.

The proposed methodological design comprises four sequential phases that lead to the generation of an initial version of a roadmap (recommendations) to pursue a distinctive sign (designation of origin/geographical indication) (Figure 1). The following details are each of the proposed phases.

2.1 Phase 1 – Scientific Intelligence

In this phase, methodologies for scientific monitoring of strategic knowledge areas in R&D&I and scientometrics were integrated. Based on the identification and selection of parametrized scientific and technological information resources (indexed and standardized sources), structured information retrieval (metadata and full-text content) was developed from the main scientific information databases available to AGROSAVIA, using a search strategy represented by a structured equation. The information retrieved from each database was normalized to facilitate its analysis through specialized software tools such as VOSviewer 1.6.20 (van Eck & Waltman, 2010) for cooccurrence analysis of keywords and key texts (title and abstract) and Bibliometrix 4.2.3 R Library and its shiny interface (Aria & Cuccurullo, 2017) for three filed plot analysis (country-affiliations-keywords), trend topics analysis (keywords occurrences through tine), thematic map analysis (relevant and importance classification of

topics) and multicomponent analysis (key thematic cores). As products of this phase, these results were consolidated. A structured search equation: The equation is a set of key terms articulated using Boolean operators, facilitating the retrieval of information in databases. Similarly, the equation enables the continuous retrieval of new information related to the subject matter (updating trends or implementing monitoring plans).

For this research, the following structured search equation was implemented:

TITLE-ABS-KEY(("Appellation of origin" OR "certificate of origin" OR "declaration of origin" OR "geographical indication*")) AND (LIMIT-TO (SUBJAREA,"AGRI"))

This equation was implemented in the Scopus®, Web of Science®, SciELO®, The Lens®, and Dimensions® databases. Table 1 presents the report of the publication records retrieved and consolidated from the information-mentioned sources.

A stratified library of scientific information on appellation of origin and geographical indication in agricultural products: The stratified library encompasses the baseline or core knowledge related to the study object. It is considered reference information for deepening or diversifying research approaches (object of study). Scientific landscapes of general, specific, and complementary trends: The scientific landscapes involved the construction of analytical networks of information associated with the indexing metadata of scientific publications, using data and text mining techniques.

Scientific landscape of general trends: This landscape was constructed using keywords (from both authors and indexing) associated with each publication, which represent the scope of the research, related topics, or foundational areas of knowledge to map general trends (Gerdsri & Kongthon, 2018).

Scientific landscape of specific trends: This landscape was constructed using key texts, primarily the titles and abstracts of the publications. Titles represent the research intent based on the study and work objectives, while abstracts cover topics related to the research's objective, methodology, results, and main conclusions to map specific trends (Sohrabi et al., 2019).

Thematic maps of research topic distribution and knowledge core**:** The construction of thematic categorization maps for research lines was based on a two-dimensional distribution (Callon et al., 1991; Cobo et al., 2011). The degree of relevance, also known as centrality, measures the level of interaction between a cluster and other clusters, indicating the importance of the thematic cluster within the research field. The degree of development, also known as density, measures the internal strength of each thematic cluster based on the relationships between the topics it comprises, showing the development level of the cluster. Based on these two dimensions, clusters were categorized into the following four groups (Aria et al., 2022; Giannakos et al., 2020):

Quadrant I - Motor themes (high centrality and density): this quadrant comprises thematic clusters that represent 'hot topics' or the mainstream of research. These clusters are well-developed and play a crucial role in structuring the research field.

Quadrant II - Niche themes (low centrality and high density): the thematic clusters in this quadrant, often referred to as 'ivory towers,' exhibit a high level of development but remain marginal to the research field. They may represent specialized areas or autonomous topics that contribute to subfields of research or are explored from other disciplines within the research field.

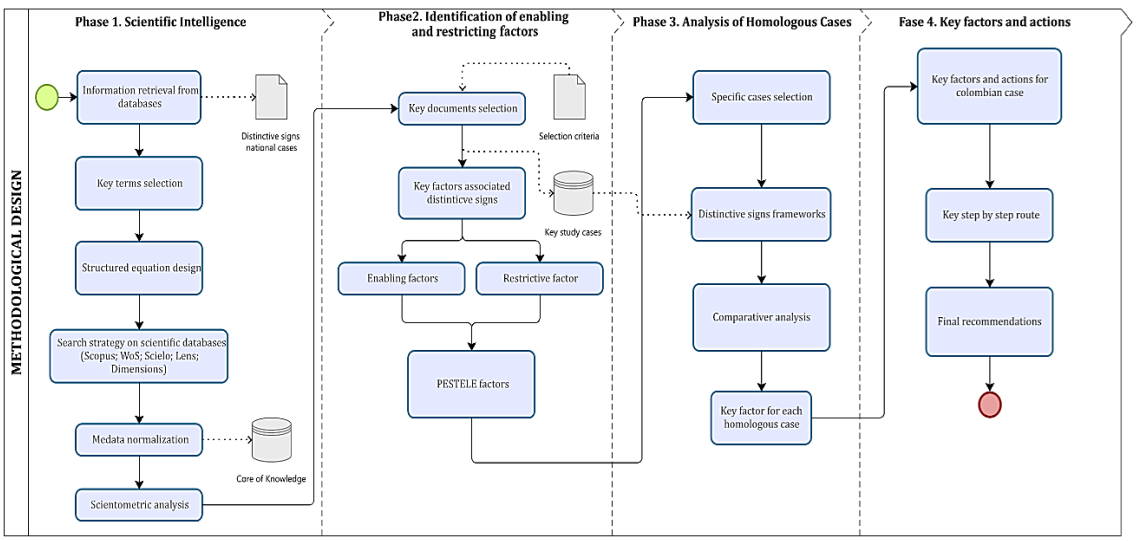

Figure 1. Research methodological design. Source. Based on Flórez-Martínez et al. (2023, 2024).

Table 1
Recovered data

	Scopus	Web of Science	SciELO	Lens	Dimensions
No. of records retrieved	1.107	356	48	787	208
No. of unique records selected	544	26	6	465	19
Total number of unique records (knowledge core): 1,060					

Quadrant III - Emerging or declining themes (low centrality and density): This quadrant identifies emerging themes ('new trends') with the potential to contribute to the research field, as well as themes that are losing importance ('fading away'). These themes may signify evolving research areas or decreasing interest within the field.

Quadrant IV - Basic or transversal themes (high centrality and low density): The thematic clusters in this quadrant, known as 'dragging topics,' are essential for the research field. However, their level of development suggests that they may represent past topics or those from other disciplines or contexts. They contribute to a deeper understanding of the research field.

Multicomponent analysis map – knowledge core: This analysis involved the identification of the core knowledge of research on distinctive signs of appellation of origin and geographical indication for agri-food products. The analysis was conducted using the multiple correspondence method, which reduces the dimensionality of scientific maps (both general and specific trends) to the main subtopics and themes that synthesize the knowledge area (Di Franco, 2016). According to Cuccurullo et al. (2016), this method facilitates: i) defining, based on word proximity, the affinity between topics (shared substance), either because a representative proportion of scientific publications within the knowledge core addresses them jointly (co-occurrence frequency) or because they are close to the origin of the correspondence map (representing the center of the research field), and ii) the two-dimensional visualization of the journal's knowledge cores.

2.2 Phase 2 – Identification of enabling and restricting factors.

This phase involved the definition of the knowledge core based on activities for selecting and prioritizing key documents. The delimitation was carried out through three stages:

Stage 1 – Refinement by study object: In this stage, the retrieved publications were reviewed, and those whose study object was related to minimally processed foods, processed foods, active ingredients, and food trademarks were excluded.

Stage 2 – Refinement by specificity of the study object: The publications selected in Stage 1 were further reviewed, and those whose study object was not a horticultural product (vegetables, legumes, or aromatic plants) covered by AGROSAVIA's Vegetable and Aromatic Plants Innovation Network were excluded.

Stage 3 – Refinement by alignment with the research study object: The publications selected in Stage 2 were reviewed, focusing on those whose study object referred to a horticultural product of the *Allium* genus. This genus includes species of interest such as bulb onions (*Allium cepa*); green onions (*Allium fistulosum*), chives (*Allium schoenoprasum*); leeks (*Allium ampeloprasum* var. *porrum*); garlic (*Allium sativum*); and shallots (*Allium ascalonicum*).

The documents selected in Stage 2 serve as an input for the development of specific analyses to identify knowledge areas, methods, methodologies, and technologies used to address issues related to distinctive signs. As a result of this analysis, generic enabling and restricting factors were established and categorized using the PESTEL+E methodology (Sheffield Hallam University, 2023), into the following:

- Political: Related to governance and public policies.
- Economical: Concerning economic variables such as costs, business models, alliances, trade agreements, and market dynamics.
- Social: Related to the involved populations, cultural aspects, interests, and associations.
- Technological: Linked to advances in R&D&I, technology transfer mechanisms, availability, access, and use; technological integration along the value chain; and the incorporation of new knowledge.
- Environmental: Related to the biophysical components of the territory, including natural resources, biotic and abiotic factors, and climate change and variability.
- Legal: Pertaining to regulatory frameworks for production, marketing, consumption, quality, safety, operational freedom, among other guidelines.
- Ethical: Concerning the implications associated with the nature of the activity.

For the specific case of the documents selected in Stage 3, these were retrieved in full text, and any available regulatory documents and certifications related to the distinctive sign granted to the product are sought for use in Phase 3.

As a product of this phase, synthetic information tables are generated, linking research documents, addressed issues, key factors, research methods, associated certifications, and general and specific trends identified in Phase 1 for horticultural products.

2.3 Phase 3 – Analysis of Homologous Cases

Based on the synthetic table constructed in Phase 2 and the documents selected in Stage 3 of that phase (reference cases identified in the literature specific to *Allium* species), a comparative analysis was conducted according to the regulations for distinctive signs of appellation of origin and geographical indication, as applicable. This analysis allowed the identification of success factors for obtaining distinctive signs, focusing on research activities that support or generate evidence facilitating certification.

2.4 Phase 4 – Key factors and steps

Based on the results obtained in the previous phases, key factors and steps were established for the "*Ocañera*" red onion variety.

3. Results and discussion

The results obtained from the implementation of the methodological design described in Section 2 are presented below.

3.1 Phase 1 – Scientific Intelligence

This section presents the results of the implementation of the scientific intelligence methodology described in the Materials and Methods section.

3.1.1 Research key stakeholders

The relationship between the search fields of country, institutional affiliation, and keywords (Figure 2) allows for the identification that research led by China and Italy has focused on agribusiness and marketing, both locally and internationally, of differentiated products through geographical indication certifications. These efforts have implemented quality controls that have, in turn, strengthened authentication processes. In these areas, the most prominent institutions from China are Heilongjiang Bayi Agricultural University, Huazhong Agricultural University, and the China Academy of Chinese Medical Sciences. From Italy, the most relevant institutions are the University of Messina, the University of Verona, and the University of Parma.

Countries and their respective institutions focused on use of distinctive signs like geographical indication as an alternative to strengthen international trade of agricultural products. Furthermore, the impact on economic growth can be associated with environmental impact.

3.1.2 Trending topics

The time trend graph of the main thematic topics (Figure 3) shows that over the past 15 years, the most frequently addressed topics, based on the occurrence frequency of keywords, are intellectual property, natural resource economics, environmental protection, trademarks, food quality, and traditional knowledge.

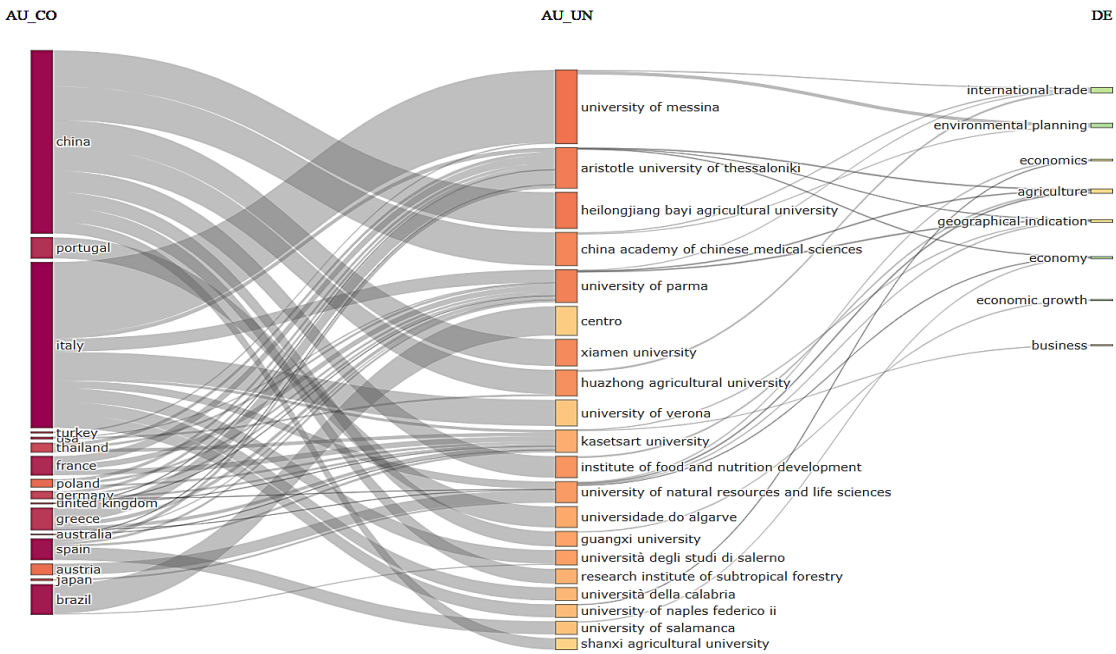

Figure 2. Sankey Diagram - Main Countries, Institutions, and Topics Related to Distinctive Signs. Source: Compiled from information in Scopus®, Web of Science®, SciELO®, Lens®, and Dimensions®. Consultation date: June 2024. Bibliometric Analysis Software: Bibliometrix® v. 4.2.3.

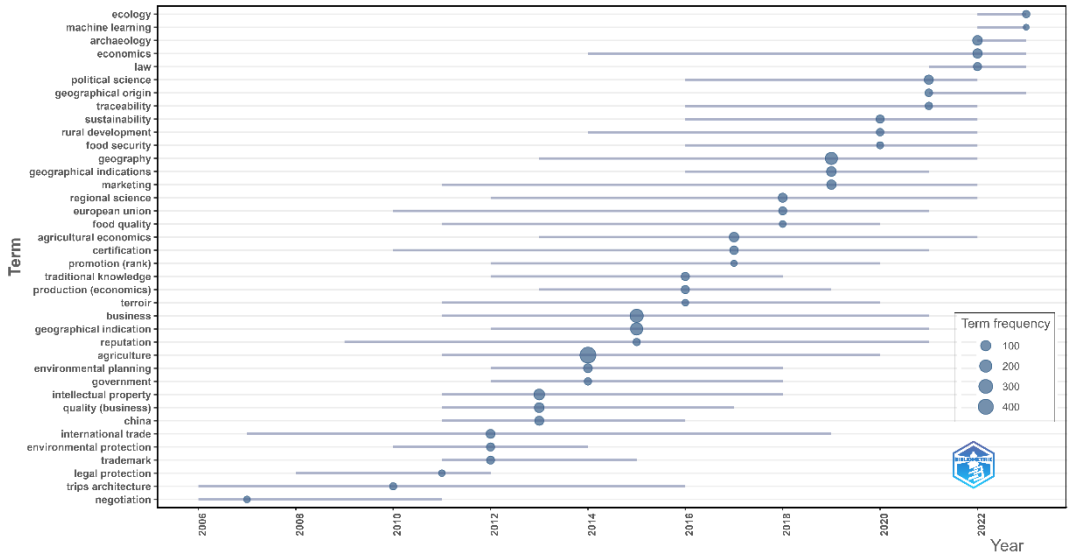

Figure 3. Temporal Trend of Topics in Distinctive Signs. Source. Compiled from information in Scopus®, Web of Science®, SciELO®, Lens®, and Dimensions®. Consultation date: June 2024. Analysis Software: Bibliometrix® v. 4.2.3.

These topics have been relevant for a period of 10 to 13 years between 2010 and 2022. Specifically, trends in traceability, tourism, consumer preferences, geographical economics, authentication, natural resource economics, and the domestic market have been of particular interest. Some other terms like certification mark and legal protection were highly related to enterprise Intellectual property strategies (Filoche & Pinton, 2014). Furthermore, according to the World Intellectual Property Organization (WIPO), distinctive signs embrace the key concept for products origin recognition and valuation.

3.1.3 Key trends

Based on the analysis of 1,060 publications in VOSviewer®, thematic clusters were identified and visualized in a co-occurrence network map based on the frequency of occurrence and the intensity of interaction between topics found in the titles and abstracts of the publications. This analysis identified seven thematic clusters, which are visualized in Figure 4 and can be differentiated by colors.

Red Cluster – Food identity and traditional foods: This cluster highlights topics related to regulatory frameworks for the legal recognition of traditional food products that possess unique characteristics specific to regions. The goal is to enhance and protect their added value, high quality, and commercial worth by integrating labels under categories such as PDO (Protected Designation of Origin), PGI (Protected Geographical Indication), and TSG (Traditional Specialties Guaranteed) (Gallagher & McKevitt, 2019; Caputo et al., 2018). This is accompanied by quality certification systems for agricultural products free from contamination, specifically in reference to green and organic foods (Du et al., 2023).

Green Cluster – Metabolite profiling: The content and concentration of metabolites in agricultural products have been foundational for the authentication and identification of regional products, particularly in determining geographical indications. The thematic topics of this cluster cover aspects of metabolite characterization through metabolomic processes, microextraction, or spectroscopy used to establish a specific standard quality by which different varieties, plant accessions, or ecotypes are differentiated (Sánchez Pérez et al., 2011; Zhao et al., 2022; Wen, 2023).

Blue Cluster – Valuation of products with geographical indication: This cluster frequently addresses topics related to the added value of products with designation of origin or geographical indication, their economic impact at the territorial level, and consumers' willingness to pay for traditional consumption products (consumer preferences) (Bryla, 2018; Cei et al., 2018). This valuation contributes to the development of local food systems and specific territories, with particular attention to ethnic foods that hold significant meaning in fair trade (El Hadad-Gauthier, 2022; Bowen & Mutersbaugh, 2014; Vural, 2021).

Yellow and Light Blue Clusters – Bioactive components: Geographical indications are determined by the characterization of components with high nutraceutical value, serving as the basis for quality control and labeling (Su et al., 2016; Delgado et al., 2023). Among these components,

flavonoids, anthocyanins, polyphenols, and fatty acids, many of which have antioxidant activity, are particularly relevant (Almeida et al., 2017; Lin et al., 2021; Taglienti et al., 2020). Additionally, organoleptic characterization is also part of the agricultural product characterization, with attributes such as aroma and pigments being the most mentioned (Arias-Carmona et al., 2012; Jarma Arroyo et al., 2020; Predieri et al., 2006; Giraud, 2008; Singh et al., 2023).

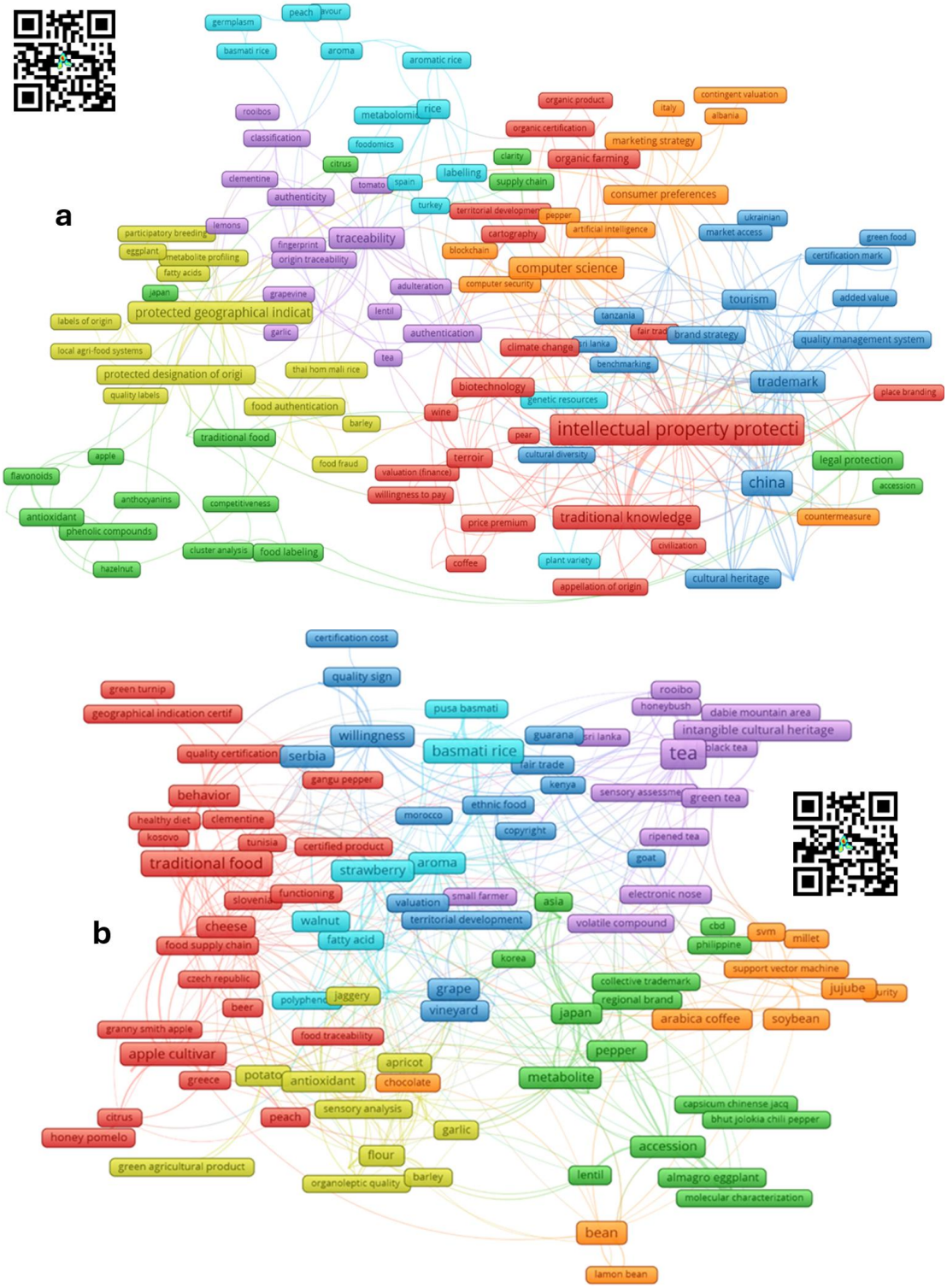

Figure 4. Key Trend Maps. Source: Compiled from information in Scopus®, Web of Science®, SciELO®, Lens®, and Dimensions®. Consultation date: June 2024. Analysis Software: VOSviewer® v. 1.6.20. (a) *keyword co-occurrence network*; (b) *title and abstract co-occurrence network*.

Violet Cluster – Intangible cultural heritage: Geographical indications for agri-food products are strongly linked to peoples and traditions, making a fundamental contribution to territorial development and identity. This has allowed the intrinsic heritage of traditional agricultural products to be highlighted and strengthened, enhancing environmental and cultural values while promoting the transmission of cultural heritage between generations and territories (Narciso et al., 2020; Gallagher & McKevitt, 2019; Castelló et al., 2023).

Orange Cluster – Traceability: This cluster emphasizes the importance of implementing traceability systems as a factor for quality, recognition, and authentication of specific characteristics in agricultural products. It is also a tool that is part of the process of protecting geographical indications, contributing to reducing the risk of food fraud and adulteration, thereby generating greater consumer confidence (De Rosa, 2015; Fanning et al., 2023; Guo et al., 2007).

3.1.4 Priority trends

As central themes with a balanced level of development and relevance or importance, the application of biotechnological innovation to the utilization of biodiversity and natural resources, as well as the higher differentiated price paid for products derived from them, stand out (Figure 5).

Motor themes (upper right quadrant): The management of cultural heritage, which is based on traditional agricultural knowledge and production, stands out as a key theme. This contributes to promoting tourism among consumers interested in foods with local and traditional identity.

Basic or transversal themes (lower right quadrant): The topics addressed in this quadrant are diverse and include the diversification of production in the territory as a marketing strategy, linked to consumer knowledge and behavior, particularly among those with preferences for value-added products. This strategy also involves intellectual property, legal protection, and the creation of trademarks that have capitalized on biodiversity and other biological resources as part of agribusiness. A third significant element in this quadrant is the labeling of foods with protected designation of origin and the willingness to pay for added value.

Specialized or "niche" themes (upper left quadrant): Relevant topics in this quadrant include the authentication of food products, where the implementation of traceability processes is crucial. These topics are also part of market strategies that have focused on promoting organic agriculture and the processed products derived from this type of production.

Emerging or declining themes (lower left quadrant): The utilization of natural resources, highlighted as an emerging theme, significantly contributes to sustainability and environmental protection in the territories.

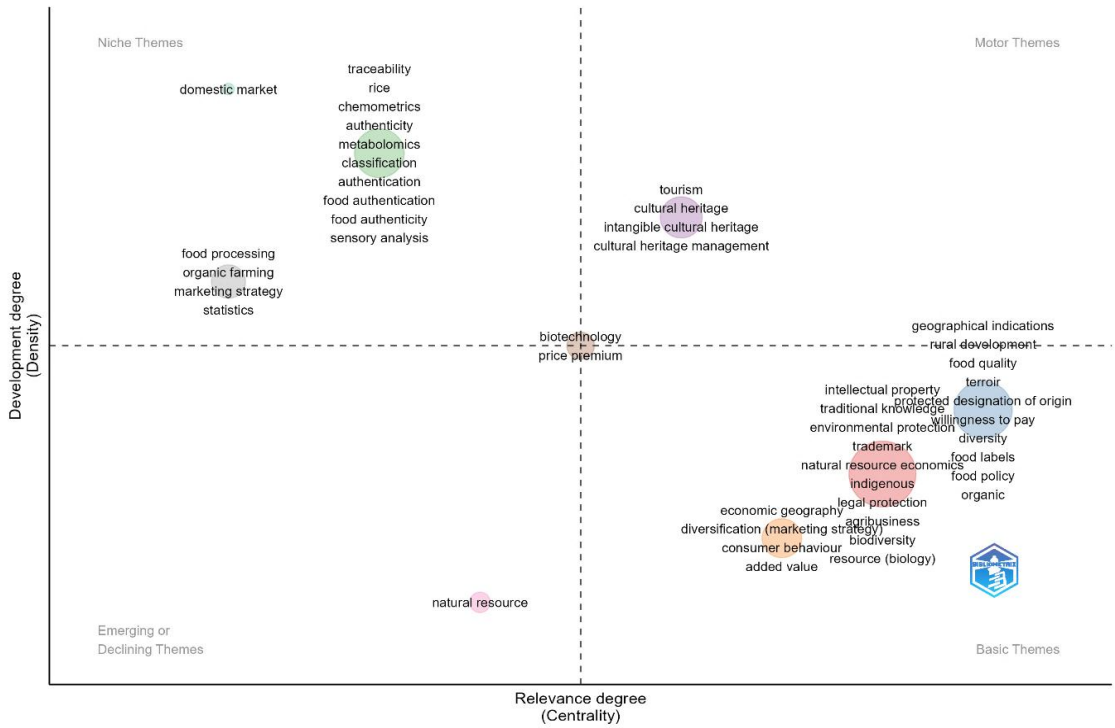

Figure 5. Thematic Map of Trend Categorization. Source: Compiled from information in Scopus®, Web of Science®, SciELO®, Lens®, and Dimensions®. Consultation date: June 2024. Analysis Software: Bibliometrix® v. 4.2.3.

3.1.5 Research core

Multicomponent or factor analysis allows for the relationship between keywords in specific documents to be identified, mapping the distance between them and, in turn, forming clusters with related themes (Figure 6).

Two groups of relevant thematic topics can be identified: the first group includes themes related to differentiated market strategies and agribusiness, with an emphasis on environmental protection and intellectual property. These are based on the utilization of natural resources and biodiversity as factors that contribute to the promotion and protection of foods and agricultural products from specific regions through geographical indications, which has increased the relevance of territories and local food systems.

In the first group or hierarchical line, the topic of traceability gains importance as a key factor for protected designations or geographical indications of origin. Its implementation significantly contributes to food quality through chemometric methods. These components have strengthened rural development in regions where agricultural products have been traditionally produced with the highest possible safety and nutritional characteristics, ensuring greater economic returns for producers.

In the second group, the use of biotechnology stands out as a relevant factor contributing to geographical indications at a specific territorial level. This leads to the legal protection of traditional products, generating economic development in specific geographic areas.

In the third group, the topics of natural resource utilization and biodiversity are intricately linked, along with the intellectual property of strategic products aimed at strengthening agribusiness and contributing to environmental protection. This group is also connected to the creation of trademarks designed to attract consumer tourism to regions and territories that have achieved economic development through designations of origin.

In the fourth group, the management of cultural heritage related to environmental factors, cultural factors in production areas, and practices that generate added value is prominent. This results in the registration of varieties of products as regional heritage. This group is closely tied to traditional knowledge that sustainably harnesses the biodiversity of the territories.

3.2 Phase 2 – Identification of enabling and restricting factors

This section focuses on the identification and consolidation of the knowledge core for recognizing enabling and restricting factors related to distinctive signs as a differentiating mechanism for agricultural products.

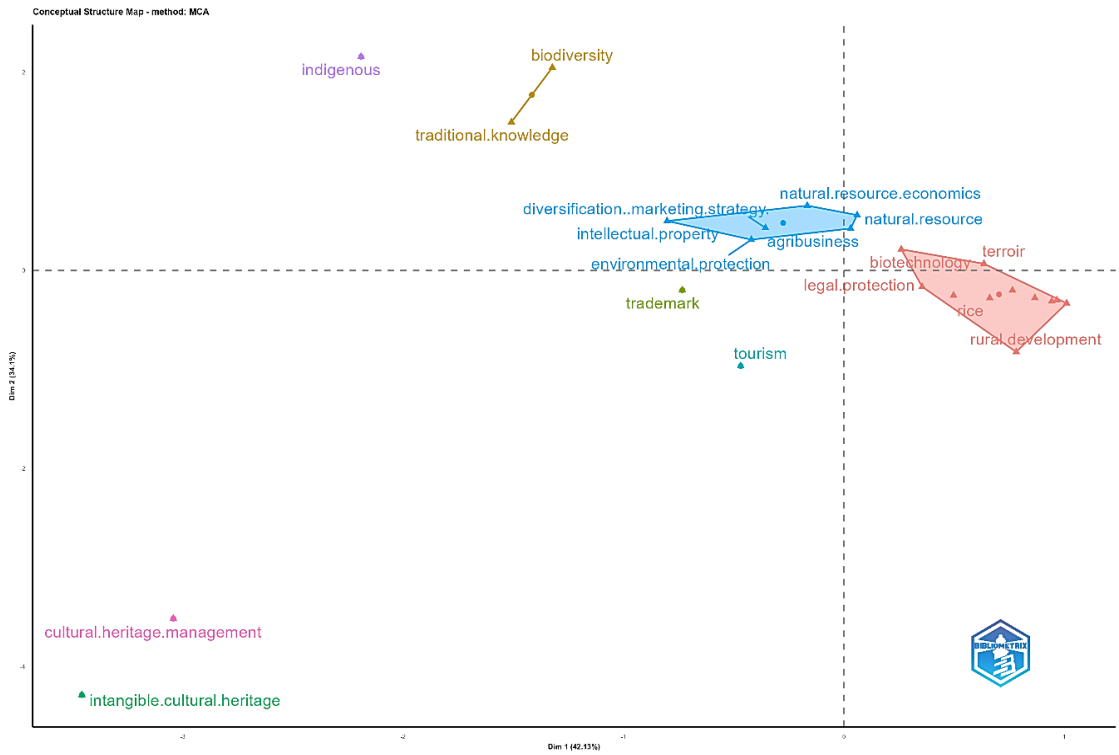

Figure 6. Factorial Map of Distinctive Signs. Source: Compiled from information in Scopus®, Web of Science®, SciELO®, Lens®, and Dimensions®. Consultation date: June 2024. Analysis Software: Bibliometrix® v. 4.2.3.

3.2.1 Refinement of the knowledge core

The identification of success factors associated with the development and implementation of a product, process, or service facilitates the design of actions that either promote their utilization (for enabling factors) or limit their impact (for restricting factors). To identify these factors, a selection and prioritization of information from the knowledge core (1,060 publication records) was conducted.

In the first refinement stage, the title and abstract of each record were reviewed to specifically determine whether the study object focuses on primary or fresh agricultural products. This analysis reduced the knowledge core from 1,060 records to 648. In other words, 412 publication records pertain to research on processed or non-agricultural products (animal-based products). The second refinement stage involved determining whether the primary agricultural product is a vegetable, legume, or aromatic plant, aligning with the scope of AGROSAVIA's Vegetable and Aromatic Plants Network. This stage reduced the knowledge core from 648 records to 110. Finally, the third refinement stage narrowed down the publication records to the Allium species. This stage further reduced the knowledge core to 15 records.

3.2.2 Identification of key factors associated with distinctive signs.

Based on the knowledge core generated in the first two refinement stages, an analysis of the titles and abstracts of the 110 records was conducted to identify the research-related knowledge area, the associated distinctive sign, the tools, methodologies, and models used in the research, and finally, the research objective. Table S1 presents the analysis of this knowledge core (See supplementary material).

The analysis of scientific publications related to geographical indication and designation of origin for horticultural products (Table S1) allows for the identification of key factors for selecting one of these protection mechanisms. To categorize these factors, the PESTEL+E methodology was implemented, which involves analyzing internal and external factors related to the study object. Table 2 presents the factors identified and categorized as enabling or restricting in an initial state of projection towards a distinctive sign.

The analysis of key factors surrounding collective distinctive signs such as PDO (Protected Designation of Origin) and PGI (Protected Geographical Indication) as alternatives to strengthen value chains, production systems, and agri-food systems offers a significant advantage: the perception and evidence of higher market quality compared to products with individual distinctive signs such as trademarks or differential quality seals (López-Bayón et al., 2020). This perceived quality influences the price set for access to the product and, by extension, the activities within the primary production chain to ensure supply meets demand. It also facilitates access to differential markets where the characteristics of the terroir and the product provide a competitive advantage (Bryla, 2018).

Being able to command differential pricing allows producers to engage in consumer expectations of paying more for a premium product, if there are mechanisms in place to support the quality offered (Ortea et al., 2016). Market dynamics affect the responsiveness of specific production models within each agricultural system and how they adapt to maintain the quality and volume offered (Mesić et al., 2017). Meeting demand in terms of volume and quality promotes the coordination of capacities among producers under the collective distinctive sign, which impacts their bargaining power, reduces intermediaries, and strengthens their position in the supply chain (Carbone, 2018). Additionally, associative actions and collaboration facilitate knowledge management, enabling the sharing of knowledge, best practices, and lessons learned (Quiñones-Ruiz et al., 2017). Associativity in knowledge management helps reduce transaction costs along the value chain and improves access to key information for decision-making, thereby reducing information asymmetries from and towards the producer (Conneely & Mahon, 2015). This directly impacts the survival of rural communities, the sustainable development of territories, and the preservation of cultural values (Rahmah, 2017; Yin et al., 2024). The main key factors that limit or restrict the expected impacts of collective distinctive signs are the costs required to meet quality and volume standards in differential markets (Ingram et al., 2020). Additionally, this can lead to poor alignment with supply chain dynamics, especially in terms of the producer's responsiveness (Bowen & De Master, 2011). It can also foster dissent among producers if there is no coordinating entity to promote trust, constructive collaboration of interests, and effective communication to reach consensus (Filipović, 2019; Quiñones-Ruiz et al., 2016). Other related limitations due to low associativity include power asymmetries along the value chain (especially concerning intermediaries) (Anson, 2018); non-consensual or collectively built reference frameworks for best practices and activities, leading to heterogeneous quality (Mancini, 2013); low integration of traditional knowledge, which inhibits social innovation (Rinallo & Pitardi, 2019); and the low availability, access, and use of strategic information related to distinctive signs throughout the value chain (from producer to consumer) (Blakeney et al., 2020).

Table 2
Enabling and restricting factors Associated with distinctive signs

Dimension	Enabling factors	Restrictive factors
Political factors	• National regulatory frameworks for the acquisition of distinctive signs (Barjolle et al., 2011). • Transnational control and regulatory entities (Dagne, 2016). • Economic policies (Raimondi et al., 2020).	• Regional regulatory frameworks for the acquisition of distinctive signs and protection in transnational commercialization (Schirone et al., 2007). • Compatibility between regulatory frameworks among countries with existing agreements or those in the process of being signed (Snyder, 2015). • Dichotomies between governance and governability in distinctive signs (Niederle et al., 2017)
Economic factors	• Competitive advantage through the impact of production costs (de Souza Meirelles et al., 2023). • Specialized market niches (Moses & Umaharan, 2014; Wynberg, 2017). • Consumption trends (Ozkan & Gurbuz, 2023).	• Consumer response dynamics (Urbano et al., 2008). • Capacity in estimating economic impact (Dogan, 2024). • Lack of awareness of benefits (Wynberg, 2017).
Social and cultural factors	• Customer value perception (De Pin & Fiore, 2022). • Cultural heritage (Miyake & Kohsaka, 2023). • Territorial heritage (Besky, 2014)	• Capacity for relationship-building and interaction along the value chain (Power relations) (Sekine, 2019). • Dichotomous aspects in social policies (Filoche & Pinton, 2014). • Capacity for integrating local, ancestral, or traditional knowledge (Karagkiozi et al., 2019).
Technological factors (associated with R+D+I processes)	• Soil characteristics, analysis, evaluation, and modeling (Borges-Gómez et al., 2014; Cai et al., 2022). • Agroecological characteristics associated with the ecosystem (Chen et al., 2022; Husaini, 2014). • Physicochemical and biological quality parameters (Romero del Castillo et al., 2021; Thomas et al., 2006). • Conservation and use of genetic resources (Bacchi et al., 2010; Brahmi et al., 2013; Singh et al., 2013).	• Unregistered varieties vs. registered varieties (Contreras et al., 2021). • Authentication technologies: availability vs. access (Firmani et al., 2019; Liu et al., 2021; Małyjurek et al., 2021; Tan et al., 2022).
Environmental factors	• Genetic diversity (Bacchi et al., 2010). • Resistance to abiotic factors (Vitti et al., 2021). • Environmental impact (Clodoveo et al., 2021).	• Influence of environmental factors (Chen et al., 2022). • Environmental impact (Dogan, 2024).
Legal factors	• Protection status (Kumar et al., 2023). • Protection frameworks for collectives (Quiñones-Ruiz et al., 2017). • Consumer protection (Urbano et al., 2008). • Producer benefits (Wynberg, 2017).	• Heterogeneous quality gaps (Romero del Castillo et al., 2021). • Potential exclusion biases due to quality (Belletti et al., 2016).
Ethical factors	• Purpose and common challenges in the value chain (Wikaningtyas & Murray, 2022).	• Purchase intention dynamics (Profeta et al., 2011).

Source: Own elaboration based on data retrieved from Scopus®, Web of Science®, SciELO®, Dimensions®, and The Lens® in April 2024. Analysis software: Microsoft Excel®.

Finally, the main limitations associated with the acquisition, maintenance, and use of distinctive signs are the low institutional capacity to support producers (Zito, 2019), which diminishes interest in obtaining them. This is linked to low incentives at the local, regional, or national levels (Nizam, 2017). In contrast, bureaucratic processes discourage the continuity and fulfillment of actions related to the distinctive sign (Bustamante, 2019), and they may open the door to "free riders" who benefit from the efforts of others without contributing to the process (Traversac et al., 2011).

3.2.3 Identification of Homologous Cases

Out of the scientific publications related to horticultural products marketed fresh, 15 publications are associated with species of the *Allium* genus. Table S2 presents the characterization of the identified cases (See supplementary material).

3.3 Phase 3 – Analysis of Homologous Cases

Based on the 15 homologous cases of scientific research aligned with or linked to the use and management of distinctive signs like Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI), characterized in Section 3.2.3, an analysis is conducted of the technical-scientific aspects addressed in each case study. This analysis compares these aspects with the regulations associated with the specific geographical context and the current regulations in Colombia.

Each identified case helps define actions that contribute to the planning, implementation, and monitoring

(management of the distinctive sign) from a scientific perspective of the designation of origin or geographical indication for horticultural products of the Allium genus. These actions can be considered best practices, lessons learned, or references to support homologous initiatives for Ocaña red onions. Table 3 presents the relationship between the scientific-technological activities developed in the publications and the specific requirements of the origin regulation of the associated country, the specific requirements of Colombian regulations, and the process stage (ex-ante, in agenda, and ex-post) for the specific cases related to red onions (seven cases).

3.4 Phase 4 – Key factors and steps

The case studies analyzed and systematized in relational Tables 2 and Table S2, serve as references for the Ocaña onion initiative, allow for the identification of key aspects to consider prior to initiating a certification process for designation of origin or geographical indication.

- Factors related to regulations: i) As collective protection rights, it is essential to have alignment and a common vision among producers regarding the challenges and benefits of protection; ii) Having individual protection signs, such as trademarks or plant breeder rights, can facilitate the process; iii) Incompatibility with local, national, and transnational marketing policies; and, iv) Strengthening activities related to conservation, utilization, and value addition.
- Factors related to the product: i) Designing protection strategies for local products; ii) Recognition of products is important for food security; iii) Recognition of local varieties with potential for individual and collective protection; iv) Identification of quality attributes that justify the design and implementation of genetic improvement programs; v) Identification of value attributes associated with food, pharmaceutical, or cosmetic functionality; and, vi) Conservation technologies.
- Factors related to the territory: i) Regional support infrastructure for certification processes; ii) The impact of globalization on cultural and economic dynamics; iii) Actions that promote the preservation of cultural and intangible heritage related to the conservation of cultural practices (e.g., agronomic practices); iv) Promotion dynamics and incentives for specific crops from public policy; v) Phenotypic and genotypic characteristics influenced by the agroecological characteristics of the terroir (e.g., shapes, flavors, aromas, and bioactive compound content); and, vi) Importance of soil resources, management practices, and sustainable use technologies.
- Factors related to available technologies: i) Technologies associated with product characterization, including morphological, chemical, nutritional content, and specific compound analysis; ii) Technologies focused on product authentication to prevent unfair competition; iii) Technologies for soil and product characterization that facilitate the traceability of terroir-conferred characteristics to the product of interest; iv) Dual-purpose technologies that can contribute to both individual signs (cultivar registration) and collective signs (geographical indication); v) Technologies related to the management of the production system (soils and water; phytosanitary management; environmental management and sustainability); and, vi) Technologies appropriate to the production models.
- Factors related to the market: i) Underdeveloped local markets and the absence of short supply chains; ii) High costs for entering differentiated markets; iii) Non-prioritized processes for the recognition of varieties; iv) Introduction of competing products through non-restrictive trade agreements; v) Traditional markets characterized by differential pricing based on quality and, vi) Traceability models based on origin determination.

Finally, one of the most innovative approaches related to the revitalization of local production systems, characterized by agroecological, sociocultural, and economic differential factors, is the one proposed by Scaramuzzi et al. (2021). They designed a five-phase methodology to analyze and characterize agri-food systems oriented towards agrobiodiversity. This methodology aims to generate a holistic analysis based on the study of complex systems, focusing on the relationships between assets, actors, processes, and effects that encompass the development of production systems with an agroecological approach. The phases of this methodological analysis were implemented in a case study on the red onion variety "*Valtiberina*" from the Tuscany region in Italy and can be suited for Colombian case:

Step 1 – Identification of biodiversity assets: In this phase, a diagnosis of the assets within the territory or specific agroecological zone of interest is conducted, focusing specifically on underutilized, orphaned, at-risk, or neglected genetic resources (plants, animals, or microorganisms). Once the resource of interest is identified, it should be characterized (using primary and secondary information) based on its distinctive qualities, including agronomic, morphological, organoleptic, and nutraceutical attributes, among others.

Table 3
Comparative analysis

Case Study	Scientific-Technological Evidence	Requirement or aspect of the regulatory framework of the case study country	Regulatory framework requirement in Colombia
Red onion variety "*Vatikiotiko*" (Petropoulos et al., 2015)	• Analysis of Chemical and Nutritional Composition • Physical, Chemical, and Microbiological Characterization of the Soil • Value-Added Functional Properties Such as Antioxidant Capacity • Analysis Technologies Supporting the Verification of Nutritional Qualities • Comparison with Commercial and Imported Varieties	• Quality Terms Facilitating Communication Between Internal Market Requirements and Value Attributes Assigned by Producers • Quality Terms Associated with Cultivation Practices or Processing Practices • Quality Terms Associated with the Technical Qualities of the Product • Quality Associated with Competitiveness, Rural Development, and Strengthening of Specific Agroecological Areas • Policies Promoting Value Addition and Its Protection	• Product quality associated with a territory • Qualities related to the biogeographical environment of the product anthropic factors (social and cultural) influencing product quality (cultural practices) factors and evidence linking biogeographical space • Characteristics of the qualities and attributes associated with the product
Onion red variety "*Tropea*", Rossa di Tropea (Furia et al., 2011; Taglienti et al., 2020)	• Chemometric Analysis • Determination of Bioactive Compound Contents Such as Flavonoids • High-Efficiency Measurement Equipment	• The use of mechanisms to protect registered designations against misuse and counterfeiting, ensuring that only authentic products can bear these quality labels. • Labels indicating PDO (Protected Designation of Origin), PGI (Protected Geographical Indication), and TSG (Traditional Specialty Guaranteed) provide clear and verifiable information to consumers about the origin and characteristics of the products, enhancing transparency and traceability in the food chain. • Compliance with strict production standards, which ensure superior quality and can justify higher market prices. • Control systems that include periodic inspections and audits to ensure that products meet the specifications of the product specification sheet. • Systems that allow tracking the product throughout the entire production chain, from raw material to final product. This ensures that any irregularity can be quickly detected and corrected.	The protection of geographical indications and designations of origin can contribute to rural development and sustainability, as it encourages local production and preserves local traditions and knowledge.
Red onion variety "*Krishnapuram*" (Vijayalakshmi et al., 2021)	• Determination of Bioactive Compounds • Antioxidant Capacity Analysis	• The law promotes sustainable practices by protecting products that have a link with the geographical environment and local traditions. • The law supports training and education programs for producers and consumers on the importance and value of geographical indications. • The specific ecological conditions of an ecoregion can influence the quality, flavor, aroma, and other characteristics of agricultural and food products. • Flavonoids and other phenolic compounds contribute to flavor and antioxidant properties. The characteristics of these compounds can be unique in different production regions. • The quality and reputation of protected products must be linked to their territory of origin, ensuring that distinctive characteristics are due to their geographical provenance. • Precise delimitation of the geographical production area. This delimitation is crucial to ensure that only products originating from the specified region can use the geographical indication or designation of origin. • The importance of natural factors (such as climate, soil, altitude) and human factors (such as cultivation practices, traditional knowledge) of the territory in the quality and characteristics of the product.	• The quality and reputation of protected products must be linked to their territory of origin, ensuring that the distinctive characteristics are due to their geographical provenance. • Precise delimitation of the geographical production area. This delimitation is crucial to ensure that only products originating from the specified region can use the geographical indication or designation of origin. • The importance of natural factors (such as climate, soil, altitude) and human factors (such as cultivation practices, traditional knowledge) of the territory in the quality and characteristics of the product. •

Red onions: "*Buzău*" variety and "*De Turda*" variety (Antofie & Sava Sand, 2017)	• Characterization • Conservation Status • Collections	• The description should highlight the specific characteristics of the variety that contribute to the product's quality and uniqueness. This may include morphological characteristics, organoleptic properties (flavor, aroma, texture), and any other distinctive features. • Local and traditional varieties often have unique characteristics that significantly contribute to the quality and reputation of products with PDO (Protected Designation of Origin) and PGI (Protected Geographical Indication).	• Recognition and protection of breeders' rights for plant varieties. These rights grant breeders exclusivity over the reproduction and commercialization of the protected variety. • The protection of plant varieties and the promotion of traditional agricultural practices can contribute to environmental sustainability and the conservation of local ecosystems.
Red onion "*Lasalgaon light*" Variety (Niphad red, Nashik red.) (Srivastva et al., 2022)	• Specific Growing Season • Organoleptic Characteristics Associated with a Strong Aroma and Spicier Flavor Conferred by the Sulfur Content in Lasalgaon's Soil • Average Size Larger Than Other Regional Varieties • 16-17 Layers of Dry Scales • Soluble Solids Between 17-18° Brix • Dry Matter Content Between 17.27% and 17.67% • Lower Weight and Size Loss Due to Dry Matter and Soluble Solids Content • Shelf Life (Storage) of 8-9 Months • Yield of 10 t/ha	**Delimitation of the Potential Denomination Area** • Zoning of the Production Area Associated with the Denomination • Latitude, Altitude, and Elevation Variables • Estimated Area of 650 ha • 1,000 Identified Producers • Proximity to Railway Systems That Facilitate Distribution to Markets • Cultural Methods of Storage and Harvesting **Territory Attributes** • Soil: Soil Type, pH, Electrical Conductivity, Drainage Quality, Major and Minor Elements • Rainfall and Average Annual Precipitation • Average Temperature • Average Relative Humidity **Factors Conferring Differential Characteristics to the Product** • Color (Light Red) • Productive Season (Winter Crop) • Flavor and Aroma: Spicy Flavor and Intense Aroma Due to Sulfur Content in the Soil • Bioactive Compounds: Vitamin B2, Vitamin C, Minerals, Calcium, and Iron • Comparison with Competing Varieties **Productive Model Factors** • Propagation Mechanism	• Recognition of the Geographical Area Due to the Special Products Originating from It • Quality Factors of Products Associated with the Territory, Soil, and Climate • Standardized Production Factors • Human Factors That Confer Sociocultural Value (Traditional Cultivation Methods)
Violet Onion "*Vihnchau*" (Thi et al., 2013)	• Variety Native to the Territory • Number of Bulbs • Intense Color • Size and Weight • Smooth Skin • Crisp Texture • Pleasant Pungent Odor • Moisture Content of 73.08 ± 2.08% • Total Sulfur Content Not Less Than 723.1 mg/100g • Total Sugar Content 7.5 ± 0.3% • Total Soluble Solids 11.4 ± 0.66 °Brix • Lower Bulb Density Facilitates Cutting	**Territory Characteristics** • Tradition and Experience of the Growers • The Deposits in the Geographical Area Consist of Clay, Sand, Fine Particles, Plant Debris, Shell Fragments, which Contribute to formulating Sandy Clay Soils • High Rainfall • Low Temperature Variation (2.08°C) **Productive Model Factors** • Agronomic Management • Irrigation Management	• Recognition of the Geographical Area Due to the Special Products Originating from It • Quality Factors of Products Associated with the Territory, Soil, and Climate • Standardized Production Factors • Human Factors That Confer Sociocultural Value (Traditional Cultivation Methods)

This also involves assessing its value attributes or competitive advantage (reputation), its conservation status or risk, and its interrelationship with the territory and other assets such as history, traditional practices, and knowledge. This phase should produce guidelines for conservation, utilization, or quality enhancement. In the case study, this characterization led to the registration of the variety in both regional and national variety registries, supported by technical assistance to producers and the delimitation of the production area (terroir) for in situ conservation, use, and seed distribution.

Step 2 – Activation of agrobiodiversity assets and stakeholders (territorial actors): This phase involves mapping social actors or stakeholders who interact with the biophysical component or the agri-food system. The goal is to establish the level of commitment from producers, processors, marketers, and final consumers (local/non-local; public/private) in developing actions that contribute to the registration of local varieties, the establishment of product qualities, the characterization of chain interrelationships, as well as the conservation and restoration of genetic resources and the knowledge associated with them. For the *Valtiberina* onion case study, a collective action was identified among producers from the original Tuscan terroirs in *Sansepolcro* (Arezzo), along with local research centers and regional agricultural institutions. This collective effort led to the characterization and registration of the variety in local, regional, and national cultivar banks, minimizing the risk of extinction and engaging actors interested in preserving the material.

Step 3 – Qualification of products derived from agrobiodiversity assets: In this phase, the efforts of public or private actors have materialized in recognizing the social value of biodiversity assets and their derived products. This involves identifying and selecting potential tools to qualify and add value, such as collective trademarks, designations of origin, registration in public seed registries, commercialization of propagation material, geographical indications, among others. In the case study, the collaboration between seed custodians, producers, and other supply chain actors facilitated governance through formal and informal agreements, product valorization strategies, and management processes. Additionally, differential factors were identified in terms of logos, packaging, distribution routes for products made from the onion variety (e.g., flan), and access to a traditional variety registration in Tuscany, which has diversified its culinary uses, established a differential price compared to other varieties, and created mechanisms for involving new producers, among other benefits.

Step 4 – Remuneration of agrobiodiversity assets and products: In this phase, individual and collective actions of the actors involved in developing marketing strategies for product and service valorization are identified. These strategies include defining pricing, placement, and promotion; segmenting specific and non-specific niches; focusing on generating public value; structuring the agri-food system; and strengthening the actors involved.

Step 5 – Reproducibility of agrobiodiversity assets: This phase involves designing actions to ensure their preservation, strengthening, and renewal. These actions address sustainability factors in production, equitable access to economic dividends, environmental impacts, and the social balance of the product. For the case study, key aspects include seed recirculation, agroecological production, multi-actor governance aligned with intellectual property elements, and key principles for forming and formalizing the value chain. This is reflected in the provision of private goods and services (processed products like flan, local gastronomy, pigments derived from production surpluses, best practices for the recovery and conservation of local varieties) and public goods (local variety designation, genetic resource characterization sheet, seed circulation control, terroir preservation, agricultural practices, consumption habits, soil and water conservation practices, strengthening of local know-ledge about the variety, design of tourist experience routes related to the variety, identification of bioactive compounds).

Table 4 represents the factors and steps integration route for pursuing distinctive signs of geographical indication in *ocañera onion*.

4. Conclusions

The diversification of local horticultural agribusinesses in the country should not only include research results that improve the quality, safety, availability, and accessibility of fresh products but also innovation in products, processes, and services that contribute to value addition and the inclusion of differential certifications related to quality, production methods, distinctive signs, among others. This implies that research, transfer, adoption, appropriation, and adaptation of knowledge and technologies must be approached from a value chain perspective, considering the effects on both upstream (input suppliers) and downstream (processing, marketing, final customer, and end consumer) stages to ensure the traceability of variables associated with a competitive or comparative advantage.

Table 4
Factors and steps integration route for pursuing distinctive signs of geographical indication in *ocañera onion*

Methodological Stage (Scaramuzzi et al., 2021)	Factors by Category Associated (inputs)	Key Process Activity (transformation)	Expected Outcome (milestones)
Step 1 – Identification of biodiversity and genetic assets	• Product (i, iii, iv, v); Territory (v, vi); Technology (i, iii)	Diagnosis of the territory and its biodiversity assets, characterization of local varieties in terms of differentiating attributes, protection potential, and valuation.	Identification and documentation of agrobiodiversity resources with differential value, generation of technical bases for registrations and certifications.
Step 2 – Activation of actors and agrobiodiversity assets	• Territory (i, iii, iv); Market (iii, v)	Identification and articulation of key actors (producers, marketers, regulators, scientists, consumers) around product valorization and certification.	Creation of collaboration networks and governance, alignment of actors towards certification and valorization of local production.
Step 3 – Qualification of products derived from agrobiodiversity	• Regulations (i, ii, iv); Product (ii, iv); Market (v, vi)	Development of certification mechanisms, collective protection (designations of origin, geographical indications), and individual protection (trademarks, registered varieties).	Implementation of certification schemes and product differentiation in the market.
Step 4 – Remuneration of agrobiodiversity assets and products	• Market (i, ii, iv, vi); Territory (iv)	Implementation of commercialization strategies, market niche segmentation, and product promotion with differential value.	Strengthening the competitiveness of the product in differentiated markets, generating added value and increasing income for the actors involved.
Step 5 – Reproducibility of agrobiodiversity assets	• Technology (iii, v, vi); Regulations (iv); Territory (vi)	Implementation of sustainable practices to ensure product conservation and its agroecological environment.	Sustainability of the production system, development of resilient production models, conservation, and valorization of agrobiodiversity resources.

Specifically for fresh horticultural products generated at the primary production level (including segments of the ACFEC link; small, medium, or large-scale production; producer associations; among others), having the backing of a distinctive sign not only improves their position in local and international direct consumption markets but also in niche markets where they are considered as differential raw materials for processed products. Distinctive signs like Protected Designation of Origin (PDO) or Geographical Indication (GI), as well as organic, fair trade, environmental conservation, or good agricultural practice labels, are not just labels indicating product characteristics but also evidence of research processes that support: i) the quality and differential value of the variety (planting material from available varieties like *Burguesa f1*, *Común*, *Híbrido rojo f1*, and *Rosada milenio f1*) from phenotypic and genotypic aspects; ii) the identification of use and functional attributes for food, pharmaceutical, or cosmetic applications through omics technologies; iii) the incorporation of conservation technologies and quality and safety traceability along the supply chains (transportation and storage); iv) factors related to the terroir's properties, especially soil (nutrients, biome, microbiome), water (quality of water sources), biogeographic space (temperature, humidity, altitude), and sociocultural components (cultural practices); v) available technologies for the production system related to integrated management, pest and disease control, soil and water management, harvest and post-harvest handling, environmental management, and sustainability; and vi) the design of research aimed at ensuring the authenticity of products protected by these distinctive signs to mitigate adulteration, undesirable trade, and the introduction of substitute products that undermine the local product.

For the specific case of the Ocaña Red Onion, pursuing a route to obtain a distinctive sign like PDO would incentivize its cultivation with a focus on traceability not only in management practices but also in the use of high-quality planting materials (preferably elite materials). This would strengthen the design of a specific production model for the terroir, contribute to the design, development, and adoption of sustainable technologies along the value chain, and facilitate the product's entry into differential market niches aligned with the species' differential attributes (antioxidant, nutraceutical, and health-beneficial properties). Moreover, such initiatives help strengthen the associativity and articulation of value chain actors, enabling the alignment of traditional, scientific, and decision-making capacities under a common vision.

Finally, the scientific research necessary to provide technical support for the qualities conferred by the Ocaña territory on the red bulb onion, as well as research related to the systematization of the territorial production system (production model), is essential. Future research should focus on the

integration of innovative strategies that enhance the competitiveness and sustainability of local horticultural agribusinesses by aligning scientific advancements with market demands and certification requirements. Ocaña Red Onion agribusiness, further research should strengthen the technical and scientific foundations necessary for obtaining distinctive signs by focusing on: i) the genetic and phenotypic characterization of elite planting materials to optimize quality and productivity; ii) the identification of bioactive compounds through omics technologies to highlight their nutraceutical and health benefits; iii) the development and adoption of post-harvest conservation technologies that guarantee food safety and product integrity; iv) the assessment of terroir-related factors (soil microbiome, water quality, altitude, climate conditions, and sociocultural practices) that contribute to the onion's unique characteristics; v) the integration of sustainable production technologies for soil and water management, pest and disease control, and environmental sustainability; and vi) the protection against adulteration and the introduction of substitute products that undermine the value of locally certified products. Additionally, the systematization of the territorial production system is essential to designing a scalable and replicable production model tailored to the terroir. Future work should also explore socioeconomic and policy-based incentives to strengthen associativity among producers, enhance their negotiation capacities, and promote their integration into specialized market niches.

Authors' contribution

Flórez-Martínez, D. H: Methodology, Formal analysis, Investigation, Supervision, Writing – original draft, Writing – review & editing Visualization. **Morales-Castañeda, A.**: Formal analysis, Investigation, Writing – original draft.

Data availability

The data used to support the findings of this study are available from the corresponding author upon request.

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Conflicts of interest

Authors declare that they do not have any interest conflicts.

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