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Review

# Can Geographical Indications promote environmental sustainability in food supply chains? Insights from a systematic literature review

Silvia Falasco [a,*], Paola Caputo [a], Paola Garrone [b]

[a] Politecnico di Milano, Department of Architecture, Built Environment and Construction Engineering, Piazza Leonardo da Vinci, 32, Milan, 20133, Italy
[b] Politecnico di Milano, Department of Management, Economics and Industrial Engineering, Via Lambruschini, 4/B, 20156, Milan, Italy

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ABSTRACT

Scientific literature and regulation acknowledge the positive social and economic impacts of local food productions, especially for Geographical Indication products, but their relationship with environmental sustainability remains still to be better investigated. The current European reform of the Geographical Indications system is adopting environment protection as one of the main objectives, in conformity with the European Green Deal and Farm to Fork strategies. In this framework, the present paper is aimed to show how Geographical Indications food products are related to environmental sustainability by the means of a systematic literature review. Firstly, the relevant publications are analyzed and classified referring to the Sustainable Development Goals (SDGs) framework. Results show a contradictory picture regarding the positive and negative implications of Geographical Indications production for the different components of environmental protection (e.g., SDG 9 or SDG 12). Secondly, the literature analysis identifies four features (namely products specification, producers' environmental consciousness, role of institutions and link with the territory) of Geographical Indications that may mitigate environmental pressures, when present. Finally, after the analysis of the current and emerging European Geographical Indications regulation, policy suggestions are advanced. In particular, to enhance the environmental sustainability of Geographical Indication products, explicit environmental objectives should be introduced in Geographical Indication specification, while consciousness of producers, multidimensional cooperation and link with the territory should be strengthened.

## 1. Introduction

Recent research contributions, along with global, European, and national programs and regulations, underline the need to foster decarbonization and make the use of resources and land more efficient. Food systems play a key role in this process, considering their huge consumption of resources and environmental impacts. Food value chains represent over one-quarter of the anthropogenic GHG (Green House Gases) global emissions (Poore and Nemecek, 2018; Ritchie and Roser, 2020). Agriculture causes 50–70% of global freshwater withdrawals in the vast majority of countries (FAO, 2021), and its effects on biodiversity and eutrophication are significant (Ritchie and Roser, 2020), also considering expectation for a 60% growth in food demand by 2050 (FAO, 2018a). At the same time food production is highly dependent on temperature and climatic events, making it extremely sensitive to climate change (Filho et al., 2022).

The European food system is called to modify production methods to reduce environmental pressure, according to the definition of sustainability (Brundtland, 1987) and its three aspects (healthy society, economic prosperity, and quality of the environment) (Lozano, 2008). To achieve this goal, the European Union (EU), within the European Green Deal framework, is promoting more sustainable food production and consumption patterns (European Commission, 2020). The "From Farm to Fork" strategy operationalizes the Green Deal in the agriculture and food sector, to guarantee the co-existence of healthy people, planet, societies and economies accordingly with United Nations' 2030 Agenda and its Sustainable Development Goals (SDGs) (European Union, 2020). Food-related SDGs, some of which are strictly related to the environment, are constantly monitored by the FAO (FAO, 2022).

A core component of the European agri-food sector is food production with a Geographical Indication (GI). The potential of GIs for environmental sustainability is an understudied topic. In fact, several studies (see Section 2.1.2) have demonstrated GIs' social and economic benefits for origin territories but relatively little is known about their

* Corresponding author.
*E-mail addresses:* silvia.falasco@polimi.it (S. Falasco), paola.caputo@polimi.it (P. Caputo), paola.garrone@polimi.it (P. Garrone).

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environmental effects, as underlined also by other publications (Belletti et al., 2015; Froelich and Corchuelo, 2017). The relationship between environmental sustainability and GIs is quite controversial (Lamarque and Lambin, 2015) and there is no agreement on whether food GIs have positive, neutral, or negative impacts on the environment (Section 3). The linkage between innovation, including eco-innovations, and GIs is also far from being obvious, because of the importance of tradition for producers (Rabadan et al., 2021) and consumers (Marescotti et al., 2020). Lastly, while GI producers do not systematically consider environmental sustainability (European Commission, 2022) and the current GI regulation does not include aspects of environmental sustainability, the European Commission has proposed a new regulation introducing also some measures related to environmental sustainability.

Therefore, this study aims to systematize the extant research on GI food products and environmental sustainability. Thus, we provide a knowledge contribution to the ongoing European GIs reform and some policy insights for policymakers and producers interested in exploiting the environmental sustainability of GI food products. To address the research questions, a systematic review of the literature was conducted, selecting twenty peer-reviewed works among different disciplines inside the Scopus database. Then, as detailed in the following sections, the selected references were assigned to different SDGs through a manual coding process and the drivers behind environmental impacts are addressed in light of the proposed regulations. Lastly, the different opinions regarding the insertion of environmental sustainability criteria inside the GI specification are discussed, in light of the European Commission proposal for a reform of the GI system (European Commission, 2022).

## 2. Materials and methods

The materials used in the research deal with GIs definition, characteristics and relationship with sustainability (Section 2.1). This section also describes the methodology used to conduct the literature review (Section 2.2).

### 2.1. Materials

#### 2.1.1. GI definition and characteristics

GIs are "*names which identify products that originate in a specific place, whose quality or characteristics are attributable to their geographical origin*" (European Union, 2012). GI certification requires a group of producers to promote and safeguard the product as well as a product specification containing information about the area of production, production processes, raw material traits, and final product characteristics. They include two schemes: PDOs (Protected Designation of Origin) and PGIs (Protected Geographical Indications). PDOs have a stronger link with the territory because of the mandatory localization of the entire production process and of the provenance of raw materials. Conversely, PGIs require only one phase to be localized in the territory.

GIs are produced mainly inside the European Union (approximately 94%), with Italy being the main producer, equal to the 25% of GI production (Fig. 1).

In Europe, the sector of GIs is strategic, since, in 2017, it has generated 77.15 billion Euros in sales, corresponding to the 7% of the entire EU food and agriculture sector (European Commission, 2021). GIs production and demand have been constantly growing, both in terms of number of registered GIs and in terms of economic value produced (European Commission, 2021). Typical and local productions (such as GIs) are increasingly searched by some consumers, in opposition to industrial production methods (Fernández-Ferrín et al., 2019). Conversely, other consumers are more interested in the price or other certification schemes, rather than the GI mark (Di Vita et al., 2021). Yet the GI mark can represent a good marketing tool, to promote local and traditional productions.

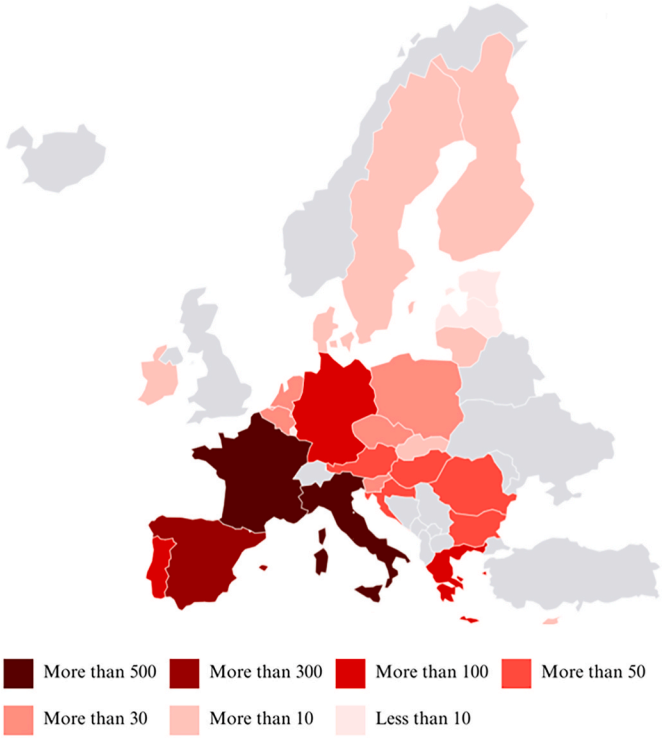


**Fig. 1.** Number of GIs produced in EU.
Data source: eAmbrosia database (accessed last: 05.07.23)

#### 2.1.2. GIs and sustainability

From an economic perspective, the introduction of a GI is accompanied by an increase in the final product price (FAO, 2018b), which is on average 2.07 times higher compared to the conventional alternative price (European Commission, 2021). Yet, the higher final price is motivated by higher production costs. This increased price produces an increase in producers' income (FAO, 2018b) provided that the added value is redistributed fairly along the supply chain (FAO, 2009). In addition, price volatility is lower in the GI sector than in the conventional market (European Commission, 2021). Another economic advantage is related to their market presence: from more robust market channels due to higher recognition by consumers, to the survival of niche products (FAO, 2009). GIs can facilitate the access to new markets for producers (FAO, 2009, 2018b) because they provide consumers with more complete and transparent information, increasing consumers' willingness to pay (FAO, 2018b). However, this mechanism also depends on consumers' knowledge of the certification (Goudis and Skuras, 2021).

GIs can positively affect social and cultural sustainability. GIs protect the traditional production processes and know-how of the local workforce (FAO, 2009) by promoting cultural and gastronomic heritage (FAO, 2018b). In addition, the presence of GIs diversifies and maintains rural activities in territories, increasing the availability of local jobs and contrasting the abandonment of dispersed areas (FAO, 2009, 2018b). GIs' production can be crucial for promoting local sustainable development initiatives in rural regions (Sgroi, 2021). Finally, GIs can be associated with an increase in local tourism activities (FAO, 2009, 2018b), which can lead to an increase of local jobs and territorial liveliness. Social and economic benefits might differ depending on which GI scheme is applied, with PDOs usually having more significant benefits for territories (Poetschki et al., 2021), and also depending on the context and product characteristics (Cei et al., 2018). The GI literature has also emphasized that local factors, which might affect GI establishment and maintenance, are essential to a GI's effectiveness and long-term viability in a given area. In other words, it is not always easy to establish a strong

"chain of causality" between GIs and the externalities produced (Vandecandelaere et al., 2021). However, environmental sustainability is instead less analyzed by literature as demonstrated by our results.

Even if traditionally, it is not included as a separate dimension of sustainable development, governance can be added to the three pillars of sustainability as suggested also by FAO through the SAFA approach (FAO, 2014). To analyze the governance dimension, the SAFA approach leverages on the already-existing corporate social responsibility instruments and extends the prior institutional dimension of the UN framework.

In the European framework, the Regulation (EU) 1151/2012 officially defines GIs, along with all the rules that producers and their organizations must comply with. This regulation specifies also the protection guaranteed to these products and their role in relation to sustainability. Regarding economic and social sustainability, the Regulation stresses positive impacts on rural economies and fair remuneration for producers. This is coherent with the original aims of GI certification, namely, to guarantee to producers a fair return for the quality of their products, to protect the names of their products, and to provide clear information on quality attributes for consumers in response to their increased price (European Union, 2012; European Union, 2022). Traditionally, environmental sustainability was not introduced as a core part of the legislation, except for a quick reminder of the need to meet the specification requirements aimed at protecting natural resources or improving the welfare of farm animals (European Union, 2012). The EU Commission "*Proposal for a Regulation on European Union geographical indications for wine, spirit drinks and agricultural products, and quality schemes for agricultural products"* (European Commission, 2022) suggests the willingness to increase the contribution of GIs to environmental preservation, as one of its six main objectives (Fig. 2). The main lever offered to producer's organization, in this matter, is the opportunity to include sustainability commitments inside the specification.

### 2.2. Methods

To cope with the research questions, the method chosen was a systematic literature review, which in order to be reliable, requires a strict structure which is here described following the step-by-step approach of Cicea et al. (2023).

Step 1: Selection of database and formulation of the final query

The selection of database is important since it can have an impact on the final result. The chosen database was Scopus, that, in the framework of the scientific articles, has a larger Journal coverage compared to other databases, such as Web of Science (Mongeon and Paul-Hus, 2016). For the formulation of the query, the results obtained through different combinations of synonyms in the query were manually checked and compared, progressively refining the initial query, which aimed to identify a sample of significant publications for the literature review, ensuring that the topics of the present research were addressed. The final version of the query, used on March 24, 2023, provided an initial set of 672 articles and it corresponds to the following:

*TITLE-ABS-KEY ("sustainab*" OR "economic* growth" OR "economic* develop*" OR "environmen*" OR "territor* develop*") AND TITLE-ABS-KEY ("geographic* indication*" OR "geographic* denomination*" OR "designation of origin")*

Step 2: Refinement of the list of selected articles

Further restrictions were applied to the type of articles and journal subjects. Only articles or reviews published in scientific journals and written in English were considered. Books and book chapters were excluded. This reduced the number of articles, from 672 to 465. Subsequently, only articles published in journals belonging to one or more of the relevant disciplinary subjects were accepted, namely "*Agricultural and biological science*"; "*Environmental science*"; "*Business, management, and accounting*"; "*Economics, econometrics, and finance*"; "*Engineering*". These subjects were chosen because they deal with scientific or economic principles, technological applications, business models, impact assessment, and innovations that contribute to advancing environmental sustainability in the agriculture and food sector. Articles published before 2012 (the GIs Regulation year) were not considered. This resulted in a final set of 345 articles.

Step 3: Abstract screening

An abstract screening was made. Firstly, articles dealing with non-food related topics, such as wine, spirits, textiles or artisanal products were excluded (73 excluded). Then articles dealing with geographical indications but not referring to the EU schemes were excluded (121 excluded), then articles that did not address sustainability at all were excluded (71 excluded). This left 80 articles dealing with GI and sustainability of which 51 treated more or less in depth the environmental side of sustainability. In case of uncertainty about criterion fulfilment or unclear abstracts, the papers were retained to maximize sensitivity and minimize false negatives. A spot check was also performed, to assure that the papers were selected correctly.

Step 4: Full-text screening.

The fourth step consisted of full-text analysis of 51 articles to confirm the selection process previously described. Articles dealing with only one GI product, considered as a case study without producing any general conclusions, were excluded (e.g., Bava et al., 2018; Dalla Riva et al., 2018; Famiglietti et al., 2019). Finally, articles investigating only the social, cultural, or economic aspects of sustainability without addressing environmental issues (just mentioning them) were excluded (e.g., Belletti et al., 2017; Flinzberger et al., 2022). One article – Barrera (2020) - was excluded since the authors did not have access to it. The complete selection process resulted in a final list of twenty significant articles, out of 51 articles analyzed in depth.

Step 5: Word cloud analysis.

To identify differences and similarities of the selected papers, a word cloud analysis was performed. In particular, the word frequency inside the title, abstract and keywords of all the selected papers has been calculated. After, prepositions and meaningless words have been removed (e.g., "in", "on", "that", "small") as well as the words that were repeated less than 10 times. After that, the "GI"- "GIs"- "Geographical Indications" and "product"- "products" words have been unified. Then the word cloud was generated with the website WordArt.com and the results were commented (Section 3.1).

Step 6: Deductive coding

As a sixth step, deductive coding was performed to categorize the publications using the Sustainable Development Goals (SDGs), and their targets as classes. Indeed the 2030 Agenda represents the most recognized, general, and comprehensive way to operationalize the multifaceted concept of sustainability and its different implications for society, the economy, and the environment. The deductive method applies a predefined dictionary of keywords, anticipating core concepts that are expected to be present in the data (Azungha, 2018). The definition of each SDGs target was analyzed to develop a dictionary that covers the most

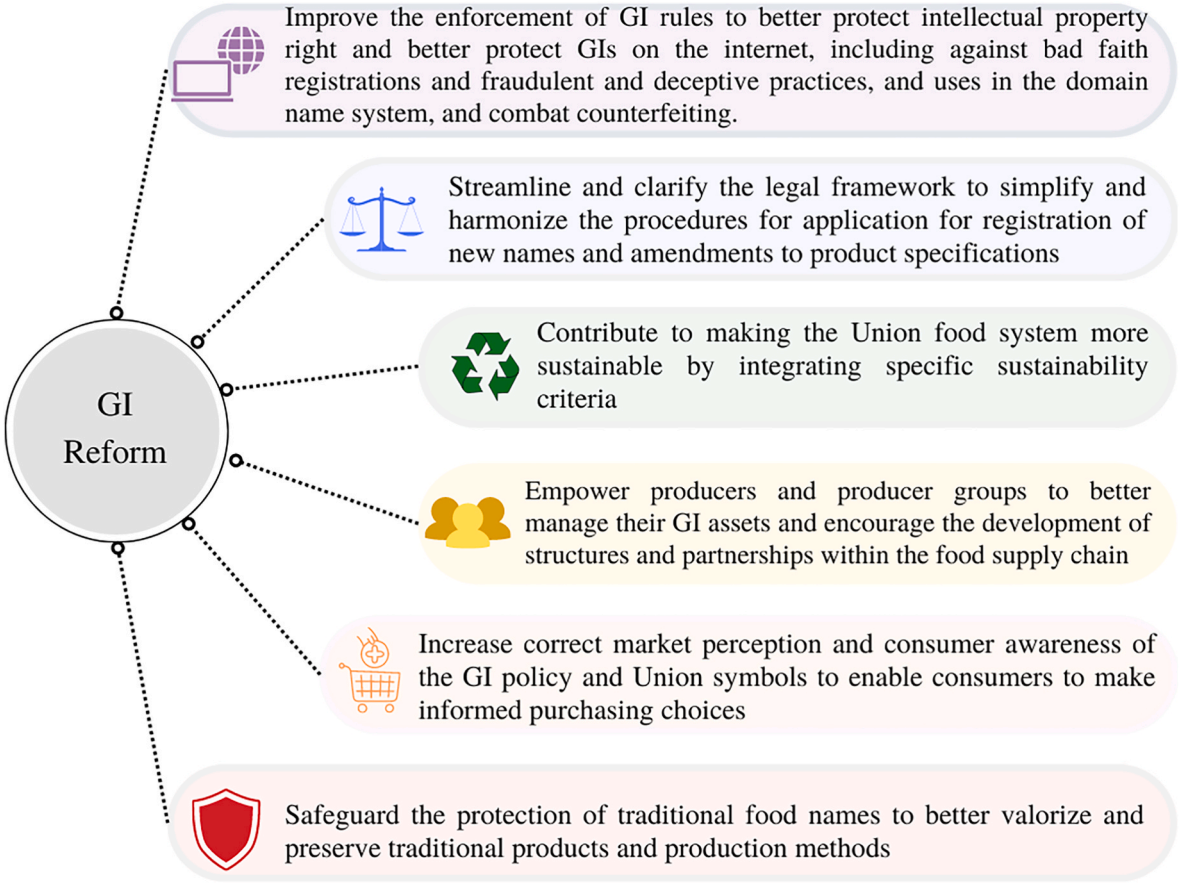


**Fig. 2.** – The six main objectives of the EU reform of GIs
(Authors' elaboration based on European Commission, 2022).

relevant and distinctive words or short phrases of the target definitions (Table 1). To do that, the definitions[1] of each SDG and of each target proposed by the United Nations were analyzed. The SDG target definitions were then coded by extracting all the keywords, related to the environmental pillar, which are those words that are unique to the target (not retrievable in other targets) and that are specific to the context of the reference SDG. Only SDGs containing at least one environmental target were taken into consideration and used for the coding procedure. In Section 3.2, the findings were discussed according to their arguments and results related to the environmental impacts of GIs. To this aim, the impact categorization offered by the Life Cycle Assessment (LCA) approach is adopted (ISO, 2020a; ISO, 2020b), since this analysis is one of the most recognized systems to evaluate environmental impacts. The LCA indicators of impacts are resource depletion, water depletion, ecotoxicity, climate change, land use and soil quality, eutrophication, acidification, and ozone depletion.

Step 7: Inductive coding

Lastly, this step is related to the application of inductive coding on the selected papers, since the articles clearly argue that GIs impacts on the environment are not univocal, but generally are moderated by drivers. Inductive coding requires the conclusions to be derived directly from the actual data analysis, rather than deductively from an a priori framework (Azungha, 2018). This means that instead of being predefined, codes and categories are recognized and designated as the researcher looks through the data (Bingham, 2023). The inductive coding methodology is commonly used to perform systematic literature reviews (e.g., Berger-Höger et al., 2023; Molléri et al., 2023). The main limitation of inductive coding is its dependency on the authors' expertise by-definition and on the general results of the review. After the inductive coding, four main drivers were individuated and analyzed, as described in Section 3.3.

All the steps of the methodology are summarized in Fig. 3.

## 3. Results

The results from the word cloud scheme are shown and commented in Section 3.1, while in Section 3.2, the relation between GI products and SDGs is deeply analyzed, starting from SDGs that are most frequently addressed by the selected publications. Then in Section 3.3, drivers, i.e., factors that may moderate the impacts of GIs on the environment, are defined and commented. In section 3.4 insights about the inclusion of sustainability criteria inside the specifications are discussed.

### 3.1. Analysis of the word cloud scheme

Fig. 4 shows the word cloud scheme created as described in Section 2.2. The color, along with the dimension of the word, identify the most repeated words. In particular, the frequency of the black words within the text corpus (titles, abstracts, keywords of the 20 papers) is higher than 50. Other frequencies amount to 30–50 for blue words, 15–30 for the green ones and less than 15 for the grey ones.

The most used words are "GIs" (and its synonyms, see 2.2.; in black). "PDO", "Environmental", "products", "food" and "sustainability" (and synonyms; in blue) follow. These results confirm the semantic selection of papers, since only papers that treat both GIs and the environmental

[1] United Nations definitions were taken from https://sdgs.un.org/goals.

**Table 1**
Relevant SDGs with related targets and used codes.

| SDGs[b] | Definition | Targets | Code#1[a] | Code#2[a] | Code#3[a] |
|---|---|---|---|---|---|
| SDG 2 | End hunger, achieve food security and improved nutrition and promote sustainable agriculture | 2.3 | Agricultural productivity | | |
| | | 2.4 | Sustainable food production | Maintain ecosystems | Land and soil quality |
| | | 2.5 | Genetic diversity | Traditional knowledge | |
| SDG 6 | Ensure availability and sustainable management of water and sanitation for all | 6.3 | Water quality | Water pollution | Recycling of water |
| | | 6.4 | Water-use efficiency | | |
| | | 6.5 | Water resources management | | |
| | | 6.6 | Water-related ecosystems | | |
| SDG 7 | Ensure access to affordable, reliable, sustainable and modern energy for all | 7.2 | Renewable energy | | |
| | | 7.3 | Energy efficiency | | |
| SDG 9 | Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation | 9.2 | Sustainable industrialization | | |
| | | 9.5 | Innovation | Scientific research | |
| SDG 11 | Make cities and human settlements inclusive, safe, resilient, and sustainable | 11.2 | Transport systems | Mobility | |
| | | 11.4 | Natural heritage | | |
| | | 11.6 | Air quality | Impacts of cities | |
| SDG 12 | Ensure sustainable consumption and production patterns | 12.2 | Efficient use of resources | | |
| | | 12.3 | Food waste | | |
| | | 12.4 | Release to air, water and soil | Use of chemicals | |
| | | 12.5 | Recycling and recovery of waste | Waste | |
| SDG 13 | Take urgent action to combat climate change and its impacts | 13.1 | Resilience | Climate events | |
| SDG 14 | Conserve and sustainably use the oceans, seas and marine resources for sustainable development | 14.1 | Marine pollution | | |
| | | 14.2 | Marine ecosystems protection | | |
| | | 14.3 | Ocean acidification | | |
| | | 14.4 | Overfishing | Fishing practices | |
| | | 14.5 | Conservation of marine areas | | |
| SDG 15 | Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss | 15.1 | Sustainable use of ecosystems | | |
| | | 15.2 | Forests management | Deforestation | |
| | | 15.3 | Desertification | | |
| | | 15.4 | Mountain ecosystems | | |
| | | 15.5 | Degradation of natural habitats | Biodiversity | |
| | | 15.7 | End poaching and trafficking | | |
| | | 15.8 | Invasive alien species | | |

[a] The last three columns contain the codes used for the deductive coding procedures.
[b] Only SDGs having at least one environmental target were considered. SDG 1, 3, 4, 5, 8, 10, 16 and 17 were excluded.

sustainability in the food sector were accepted. The word "GIs" is the most used, even though it is not present in all the abstracts but only in the papers that addressed the GI scheme in general (e.g., Owen et al., 2020; Vandecandelaere et al., 2021). The papers that analyze a particular GI product (even if pointing out general implications) use "PDO", along with "PGI" (e.g., Arfini et al., 2019b; Di Vita et al., 2018). "Food" is a word present in almost every abstract, except for five, where a more specific term identifies the analyzed products (i.e., olive oil, citrus, dairy, cheese, fruit). "Products" (unified with "production") is present in fourteen out of the twenty abstracts, and this is in accordance with the fact that the GI scheme refers to the production stage. A high frequency of this word is found in Belletti et al. (2015); Lamarque and Lambin (2015); Marescotti et al. (2020) which are papers that focus on the specification and on the production process of the GIs. Lastly, the "environmental" and "sustainability" words are not present in every abstract (e.g., Arfini et al., 2019a; Belmin et al., 2021), but these themes are analyzed with different words, for example natural resources, use of local resources, pollution, rural development.

### 3.2. Geographical indications and SDGs

The twenty selected articles have been linked to SDGs and targets through the application of deductive coding. Table 2 provides the classification of the selected articles according to their relation to SDGs and targets.

#### 3.2.1. Analysis of environmental targets

Analyzing in detail the twenty papers that have been selected for their focus on environmental sustainability aspects, Arfini et al. (2019b); Bellassen et al. (2022); Belletti et al. (2015); Coelho et al. (2017); Froehlich and Corchuelo (2017); attribute a positive effect of the GI certification on sustainability, even if Belletti et al. (2015) underlines the need of support policies to achieve it. Instead, Bermejo et al. (2021); Garcia-Cornejo et al. (2020); Girard (2022); Lamarque and Lambin (2015); Narciso and Fonte (2021); Owen et al. (2020); Vandecandelaere et al., (2021); do not suggest a univocal positive correlation between GIs and environmental sustainability. E.g., Girard (2022); underlines that other mechanisms are needed to influence environmental sustainability,

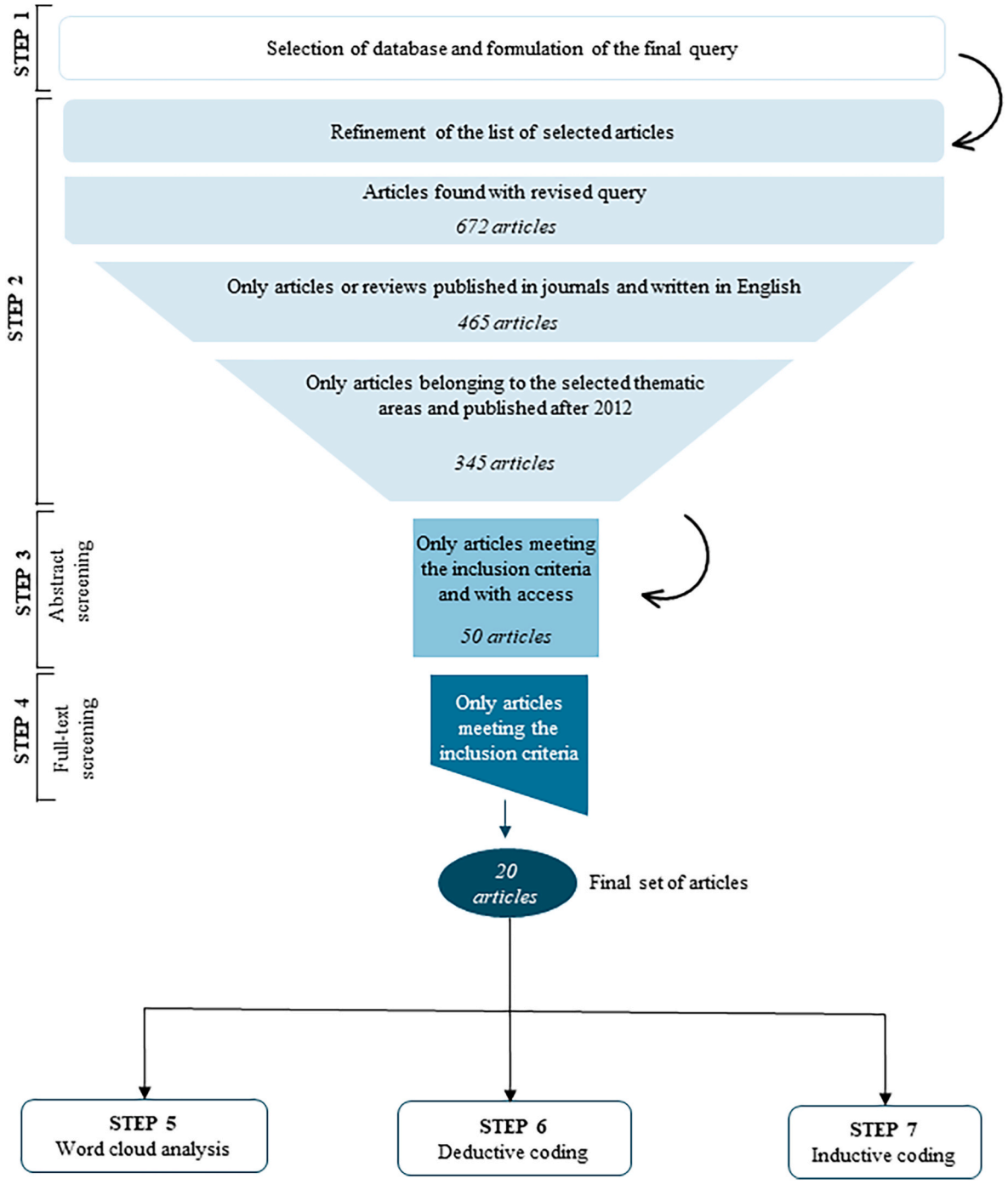


**Fig. 3.** Graphical representation of the methodology.
(Authors' elaboration).

while Owen et al. (2020); Vandecandelaere et al. (2021); stress the necessity to involve all the supply chain actors for the GIs to enhance environmental sustainability. Narciso and Fonte (2021); instead claim that GIs should not be automatically considered more sustainable, but that a case-by-case evaluation is needed. By contrast, Marescotti et al. (2020); Millet et al. (2020); Rabadan et al. (2021), suggest that the relationship between GIs and environmental sustainability may also be negative. Given that no or few environmental objectives are reported in the GI specifications, there are cases where harmful practices are allowed. Therefore, the GI certification cannot yet be considered as a driver toward the reduction of environmental impacts.

The remaining papers (Belmin et al., 2021; Di Bella et al., 2019; Di Vita et al., 2018; Garcia-Cornejo et al., 2020; García-Hernández et al., 2022) discuss a particular side of sustainability and its relationship with GIs. In particular the themes that these papers have analyzed are as follows. Belmin et al. (2021), points out that the GI certification optimizes some production processes and consequently reduces the generated waste. Di Bella et al. (2019), indicates that the PGI certification reduces the risk of contamination for final products. Di Vita et al. (2018), addresses only indirectly the PGI certification and puts emphasis on the cultivation systems (organic, conventional and integrated) that are covered by some GI scheme. Garcia-Cornejo et al. (2020) places the PDO schemes in the factors that could improve the production efficiency of the production. García-Hernández et al. (2022); shows that the


**Fig. 4.** Word cloud schema
(Authors' elaboration based on the tool WordArt.com).

introduction of a GI certification, in their case study, resulted mainly in negative repercussions for the territory, such as an intensification of the production, with negative externalities on the local environment. Sections 3.2 and 3.3 will delve into these results taking the SDGs perspectives and highlighting the moderators, in line with the reflections of Vandecandelaere et al. (2021) which stress the need of going in depth when attempting to understand the relation between environmental sustainability and GIs.

GIs are connected by the extant studies to environmental sustainability (Table 2), in particular with SDG 2 (Zero hunger) and SDG 12 (Responsible consumption and production). Eleven out of twenty studies tackled the implications of GIs for SDG2, with a focus on targets 2.3, 2.4, and 2.5. For target 2.3, Lamarque and Lambin (2015), reported that GIs can produce a positive impact on agricultural productivity. Target 2.4 was analyzed in ten studies, with reference to the influence that GIs can have on the adoption of more sustainable agricultural practices. There is not a clear convergence about the nature of the relation between GI production and sustainable production systems. From one side, Garcia-Cornejo et al. (2020) associate GI labels with a more sustainable production system, with an increased efficiency in the use of resources; Lamarque and Lambin (2015) have associated the presence of the mark to more extensive agricultural practices, due to specification requirements and Owen et al. (2020), analyzing the specifications of Wales GI products, found a more intense presence of agroecology principles in newly registered products, underlining the increasing attention of GI producers towards environmental sustainability. On the contrary, Arfini et al. (2019a) suggested that premium prices and larger margins make GIs attractive for producers, boosting the production and increasing the pressure on the environment (also target 15.1). Intensification of the production was reported also by the case study presented by Garcia--Hernandez et al. (2022), where GIs have brought problems for animal welfare and pollutants due to a more industrialized production (also target 15.1). This intensification of the production lead to a gradual abandonment of extensive agricultural practices and traditional practices such as pastoralism (Garcia-Hernandez et al., 2022). Moreover, even though many specifications contain restrictions for yield, which can be associated to a less exploitative and more environmentally sustainable production, Belletti et al. (2015) reported that the imposed yields for GIs may be the same as the yield of intensive farming.

Target 2.5 can be partially associated with Target 15.5 since they both focus on biodiversity. These two targets belong to the most analyzed, but the results are not consistent. On one side Belletti et al. (2015) argues that GI can contribute to biodiversity when the specification imposes the use of local plant varieties, which would be otherwise replaced with varieties with higher productivity. At the same time, the definition of biodiversity is associated with the concepts of variety, diversity, and multiplicity. Privileging just one species or variety over others can lead to a decrease of genetic variability (Belletti et al., 2015). Also, Bermejo et al. (2021) reported that since GI producers are more interested to quality rather than quantity, the use of local resources can help in preserving the ecosystems, avoiding exploitation.

SDG12 (Responsible consumption and production), was tackled by nine studies with particular focus on targets 12.2, 12.3, 12.4, that are described in the following paragraphs. As regards target 12.2, namely the efficient use of natural resources, Bermejo et al. (2021) reported that

**Table 2**
- Result of the classification process based on SDGs and targets.

| Articles | SDG2 | SDG6 | SDG7 | SDG9 | SDG11 | SDG12 | SDG13 | SDG14 | SDG15 |
|---|---|---|---|---|---|---|---|---|---|
| Arfini et al. (2019a) | 2.4 | 6.4 | | 9.5 | 11.2 | 12.4 | | | 15.1 15.5 |
| Arfini et al. (2019b) | 2.4 | 6.4 | | | | 12.4 | | | |
| Bellassen et al. (2022) | 2.4 | 6.3 6.4 | | | 11.2 | 12.4 | | | |
| Belletti et al. (2015) | 2.4 2.5 | | | 9.5 | | | | | 15.1 |
| | | | | | | | | | 15.5 |
| Belmin et al. (2021) | 2.4 | | | | | | | | |
| Bermejo et al. (2021) | 2.5 | | | 9.5 | | 12.2 | | | 15.5 |
| Coelho et al. (2017) | | | | 9.5 | | | | | |
| Di Bella et al. (2019) | | | | | | 12.4 | | | |
| Di Vita et al. (2018) | | | | | | | | | |
| Froehlich and Corchuelo (2017) | | | | | | | | | |
| Garcia-Cornejo et al. (2020) | 2.4 | | | | | 12.2 | | | 15.1 |
| García-Hernández et al. (2022) | 2.4 | | | | | 12.4 | | | 15.1 15.5 |
| Girard (2022) | | 6.6 | | | | 12.2 | | 14.2 14.4 | |
| | | | | | | 12.3 | | | |
| Lamarque and Lambin (2015) | 2.3 | | | | | | | | 15.1 |
| Marescotti et al. (2020) | | | | 9.5 | | | | | |
| Millet et al. (2020) | 2.4 | | | 9.5 | | 12.3 | | | |
| Narciso and Fonte (2021) | 2.4 | | | | | 12.4 | | | |
| Owen et al. (2020) | 2.4 | | | | | | | | 15.1 |
| Rabadan et al. (2021) | | | | 9.5 | | | | | |
| Vandecandelaere et al. (2021) | 2.5 | | | | | | | | |

SDG 7 and SDG 13 columns are blank to underline that no paper among the ones selected has dealt withthese goals (See Section 3.2.1).

non-GI producers focuses more on productivity and cost management, while GI producers are more focused on market and quality. This can mean that GI products can be associated with higher costs and lower resource efficiency (Bermejo et al., 2021). Opposed to that, Garcia--Cornejo et al. (2020), has bridged the PDO certification to a higher level of efficiency in the production.

Target 12.3 was analyzed by two studies. Millet et al. (2020) in their case study have found that the specification can entail high visual standards for the final product leading to the discard of 20–50% of the produced fruit for minor symbolic imperfections. GI products, however, are not usually thrown away but they can be sold, without the GI certification, as a "second category" products at a lower margin for producers. Yet, this practice has to be allowed by the specification. Therefore, if properly written the GI specification can be a useful tool to prevent and reduce food waste generation (Girard, 2022).

Five articles addressed Target 12.4, which regards the reduction of the release of pollutants and wastes in air, water and soil. Arfini et al. (2019b) observed a positive relationship between GIs and emission of CO2. Bellassen et al. (2022) results indicate that the certified products produce 27% GHG emissions less than conventional products. A bias can be determined by the inclusion of both GIs and organic products. Narciso and Fonte (2021) argue that GI products are considered healthier for people and the environment—as they are derived from traditional and less chemically-intensive agricultural techniques. Yet this statement is not always true. In fact, as shown by the case presented by Di Bella et al. (2019) no differences in residues of chemicals were observed between PGI and non-PGI product. Also, Garcia-Hernandez et al. (2022) reported that after the GI introduction an intensification and industrialization of the production process was observed which led to an increase of pollutants release in air and especially water.

Bellassen et al. (2022) also reported that certified products perform better in term of food miles (see also target 11.2), because local sourcing and consumption in domestic markets imply a smaller logistical network. However, these considerations may not be valid for all GIs. For example, De Filippis et al. (2022) reports that GIs are an effective strategy for promoting the internationalization of agricultural goods and of the region where they are produced. Also, GIs exporters are usually more profitable than non-exporters (De Filippis et al., 2022). Moreover, some GIs are considered as niche products and are sold in a domestic market with a local supply chain, however other GIs (for example Parmigiano Reggiano PDO) are the symbol of a territory, especially outside the country and so require longer and more complex supply chains. Additionally, the meaning of local, even for PDO products, is not a well-defined concept. For example, the specification of Salamini Italiani alla Cacciatora PDO appoints as area of production eleven Italy regions (about half of the whole country's territory). The logistical advantage should be analyzed more carefully, taking into consideration that different models exist in the GI schemes, with quite different distribution logistics (Arfini et al., 2019a).

SDG9 (Industry, innovation and infrastructure) is also important, with six studies focusing on target 9.5, i.e., innovation. Each GI producer has to respect the rules written in the specifications, contrary to non-GI producers which are not subject to constraints in their management decisions (Bermejo et al., 2021). Changing these rules usually entails a long bureaucratic process at the national and European level and for this reason innovations in production processes and eco-innovations can be difficult to implement (Belletti et al., 2015; Rabadan et al., 2021). Moreover, the required regulatory change may favor some producers while penalizing others, generating possible conflicts within the producers' organizations, constituting another deterring motive for introducing innovations (Arfini et al., 2019a). Innovations and eco-innovations in GIs can also be discouraged due to the GI essence of tradition-based products. In fact, tradition can be seen as a competitive advantage for producers (Rabadan et al., 2021) and also a fundamental characteristic for consumers (Marescotti et al., 2020), reducing the producers' willingness to introduce innovations that might modify the traditionality of their products (Coelho et al., 2017). In the case study presented by Millet et al. (2020), the demand was always higher than the supply, giving the possibility of maintaining the price high, reducing the need to introduce agroecological measures.

Other SDGs, analyzed by fewer studies, were SDG6, SDG14, SDG15. SDG6 was tackled by three studies, with a focus on target 6.3, 6.4 and 6.6. Bellassen et al. (2022), reported a lower (23% less) water pollution (target 6.3) in certified products compared conventional production. Regarding water efficiency (target 6.4) two articles had contrasting results. While Bellassen et al. (2022) reported that the water footprint resulted higher for certified products (organic products were also included) compared to conventional products, Arfini et al. (2019b), reported a reduced use of water sources for GI products. Preservation of water ecosystems (target 6.6) overlaps with targets 14.2 and 14.4. Girard (2022), is the only paper focusing on an issue related to the GI category of fresh fish, mollusks and crustacean. In this case study, limits to catches introduced by GI specification may have helped to maintain the ecosystem and avoid an over-exploitation of the resources. However, understanding the environmental externalities caused by the presence of GI limits is harder, compared to other product categories. SDG15 (Life on land) was tackled by many studies, with a major focus on target 15.5, which has been discussed already. Also target 15.1 was analyzed, in relation to a higher pressure on the environment, as seen in the analysis of target 2.4.

SDG13 (Climate action) was not analyzed in detail by any article, if not in relation to biodiversity conservation. In fact, regarding the resilience of agri-food systems toward climate change related events, biodiversity is receiving an increasing attention (Vandecandelaere et al., 2021). More consideration to this target is expected in the future since GI producers, and in particular PDO producers, given their linkages with particular territories, might be affected harder by climate change than more mobile non-GI producers. However, this SDG is connected and influenced by many other SDGs. SDG7 (Affordable and clean energy) was also not addressed by any article, even if measures of energy efficiency and clean energy are now fundamental for companies, including GIs.

Table 3 summarizes the main results obtained from the literature survey on GIs and environmental sustainability. The impacts of GIs can be more comprehensively illustrated by referring to the major impacts on natural environment and resources that the LCA approach describes in ISO 14040 and ISO 14044 (ISO, 2020a; ISO, 2020b). Each LCA environmental impact is reported in the first column of the table to underline its connection with SDGs. Then in Table 3 the positive and negative impacts of GIs on environmental sustainability are summarized in the last two columns) and classified to the correspondent SDG (second column).

In conclusion, both positive and negative impacts can be associated to GI production, as reported also by Belletti et al. (2015); Lamarque and Lambin (2015). The environmental performances of a GI are therefore dependent on drivers that are worth highlighting.

### 3.3. Drivers of GIs environmental sustainability

As shown in the previous section, the role of GIs for SDGs and targets is not univocal. Their environmental impacts depend on features of GIs design. The presence of all or some of these factors can facilitate the presence of positive externalities on the environment. Therefore, the analysis continued with the identification and analysis of these drivers. The most recurrent drivers were four and they were identified through the inductive coding procedure (Section 2.2). These four drivers were then classified (Table 4) and discussed. This analysis is expected to offer general criteria to fulfil in the effort to reform the European GIs.

#### 3.3.1. GIs specification

Specifications are documents that define the regulations and standards that GIs producers must comply with. Because the GI specification

**Table 3**
Summary of results and SDGs connection with environmental impacts *(Authors' elaboration)*.

| LCA INDICATORS | Selected SDGS | POSITIVE IMPACTS OF GIs | NEGATIVE IMPACTS OF GIs |
|---|---|---|---|
| RD, WD, Ec, CC, LU, Eu, OD | SDG 2 | - Higher efficiency (Use of resources)<br>- Higher agricultural productivity<br>- Conservation of genetic diversity | - Intensification/ Pressure on the environment<br>- Privileging one species/variety |
| WD, CC, Eu, Ac | SDG 6 | - Reduced water footprint<br>- Lower water pollution (*) | - Higher water footprint (*) |
| RD, CC | SDG 7 | | |
| | SDG 9 | - Collective governance can promote innovation measures | - Specification and bureaucracy<br>- "Traditionality" trait |
| RD, CC | SDG 11 | - Preservation of natural heritage<br>- Reduce food miles | |
| RD, WD, Ec, CC, LU, Eu, OD | SDG 12 | - Higher efficiency (use of resources)<br>- Less GHG emission (*)<br>- Better performances in food miles | - Lower efficiency (use of resources)<br>- Increase in food waste (standards)<br>- Higher emissions (intensification) |
| RD, WD, Ec, CC, LU, Eu, Ac, OD | SDG 13 | | |
| Ec, CC, Eu, Ac | SDG 14 | - Specification can limit overfishing | |
| CC, Eu, LU | SDG 15 | - Conservation of biodiversity | - Pressure on the environment/ intensification<br>- Privileging one species/variety |

Abbreviations: **GHG**: Green House Gas/**RD**: Resource Depletion/**WD**: Water Depletion/**Ec**: Ecotoxicity/**CC**: Climate Change/**LU**: Land Use – Soil Quality/**Eu**: Eutrophication/**Ac**: Acidification/**OD**: Ozone Depletion.
*Organic products have been also considered.

**Table 4**
Drivers affecting the relationship between GIs and environmental sustainability.

| Articles | Specification | Producers' environmental consciousness and cooperation | Governance and role of institutions | Link with territory |
|---|---|---|---|---|
| Arfini et al. (2019a) | X | X | X | X |
| Arfini et al. (2019b) | X | X | X | X |
| Bellassen et al. (2022) | X | | | |
| Belletti et al. (2015) | X | X | X | |
| Belmin et al. (2021) | X | | | |
| Bermejo et al. (2021) | | X | | |
| Coelho et al. (2017) | | | | |
| Di Bella et al. (2019) | X | | | |
| Di Vita et al. (2018) | | X | | |
| Froehlich and Corchuelo (2017) | | X | | X |
| Garcia-Cornejo et al. (2020) | X | | | |
| García-Hernández et al. (2022) | X | | | |
| Girard (2022) | | X | X | |
| Lamarque and Lambin (2015) | X | | X | X |
| Marescotti et al. (2020) | X | | | |
| Millet et al. (2020) | | | | X |
| Narciso and Fonte (2021) | X | | | |
| Owen et al. (2020) | X | X | X | |
| Rabadan et al. (2021) | X | | | |
| Vandecandelaere et al. (2021) | X | X | X | |

contains a specific set of rules for producers, it can be a powerful instrument to steer the impact of GIs toward or against environmental sustainability (Belletti et al., 2015; Narciso and Fonte, 2021). The presence of stricter rules in the specification can be associated to better environmental performances (Arfini et al., 2019b; Belmin et al., 2021), more extensive agricultural practices (Lamarque and Lambin, 2015) and contrast intensification (Belletti et al., 2015). The specification may facilitate the local sourcing of raw materials (Bellassen et al., 2022) and the preservation of biodiversity (Belletti et al., 2015; Vandecandelaere et al., 2021). For example, requirements on the type of feed (Arfini et al., 2019a), restriction about chemical use in agriculture (Bellassen et al., 2022) or specific rules about farming practices (Belletti et al., 2015) can favor better environmental performances of GI producers. Also, visual requirements can be present within the specification, generating a higher quantity of food waste (Millet et al., 2020). Not all the specifications impose these kinds of limits or rules. Moreover, the environmental impacts depend also on how these rules are written in comparison with the conventional methods (Belletti et al., 2015) and in some cases they can also unintentionally lead to negative effects on the environment (Marescotti et al., 2020).

Despite the positive impact of introducing stricter rules in the specification the analysis of Marescotti et al. (2020) indicates a problematic trend. GIs are modifying their specification with more flexible rules and toward an intensification of the production (e.g., increase in maximum yield, increase in density of plants, …). Also, Marescotti et al. (2020) indicates that the preservation of the environment is hardly the main reason to modify a specification, since usually the motivations are more related to market reason or quality and identity reasons. However, embodying environmental sustainability in the specifications may be insufficient. Producers must actively engage in it (Girard, 2022; Owen et al., 2020). For example, the reduction of food waste may be mentioned in the specification (Girard, 2022) as well as some general commitments to more sustainable practices (Marescotti et al., 2020), but without targets to achieve or monitor mechanisms, the interest in environmental sustainability is faced more symbolically, as a competitive advantage and a way to increase the reputation of a product, than substantially (Marescotti et al., 2020).

### 3.3.2. *Producers' environmental consciousness and cooperation*

The environmental impacts generated by GIs are dependent upon producers' strategies and choices. Producers who are more ecologically conscious tend to use inputs more efficiently (Garcia Cornejo et al., 2020). The introduction of GIs can increase the awareness of producers regarding the mutuality between their products and local environment (Belletti et al., 2015; Marescotti et al., 2020). This bond between the territory and GI producers is stronger than the one that the "conventional producers" have. The awareness of producers regarding the environment and their impact as well as their willingness to preserve it are fundamental for the introduction of more sustainable practices (Vandecandelaere et al., 2021). Therefore, GI producers have an increased attention toward environmental sustainability, which should lead to a higher implementation of sustainable practices. In particular, Belletti et al. (2015), use the concept of "*responsibility to place*", which

indicates that GI producers are more responsible toward the territory since it is the territory itself that allow them to produce their GI. In fact, GI producers are aware that the quality of the final product and its reputation depend on the preservation of its terroir (Girard, 2022; Lamarque and Lambin, 2015). Despite the stronger relationship with the environment, sustainability is hardly inserted in the specification, even if there is a recent increased attention to it (Owen et al., 2020). Because GIs are collectively managed, the implementation of eco-innovations and the transition to a more sustainable system can occur only with local collective actions (Owen et al., 2020; Vandecandelaere et al., 2021). The role of cooperation between the actors is therefore fundamental for developing eco-innovations, especially for small firms, which if left alone can struggle to introduce innovations (Owen et al., 2020; Rabadan et al., 2021).

#### 3.3.3. Governance and role of institutions

GIs are collectively managed and the producers' involvement in the collective decision is fundamental to pursue a higher environmental sustainability, in fact higher farmer participation is associated with better environmental impacts (Lamarque and Lambin, 2015). Negative externalities on the territories may arise when local producers' perspectives are not taken into consideration during the process of construction or modification of a GI (Vandecandelaere et al., 2021). Producers' organizations can support more environmentally sustainable practices and facilitate the diffusion of technologies and innovations (Belletti et al., 2015). The externalities generated by GI products are strictly dependent on how the GI is managed, therefore governance has a key role in achieving a higher environmental sustainability (Owen et al., 2020; Vandecandelaere et al., 2021).

Local governments and other institutions may play a key enabling role, as their economic incentives or informative measures can guide producers' behavior, also toward the introduction of innovations. Additionally, during the registration application of a GI, institutions could ask producers to submit additional evidence supporting the relationship between product quality and the region of production, such as significant environmental concerns (Belletti et al., 2015) Therefore, the current revision of European GIs policy is of vital importance for making GIs more environmentally sustainable.

#### 3.3.4. Link with the territory

Since the sustainability of the value chain affects the sustainability of the territory and the other way around (Arfini et al., 2019a), a poor link with the territory results not only in weaker economic performances, but in a negative environmental relationship as well (Lamarque and Lambin, 2015). In order to generate positive effects on the territory, the link between the GI products, the territory and traditional practices must be strong, clear, and explicit (Vandecandelaere et al., 2021), not to risk generating negative impacts on the territory (Lamarque and Lambin, 2015). Clear communication of the bond between GIs products and territory and its cultural heritage is fundamental to avoid environmental degradation, as confirmed in Marescotti et al. (2020).

### 3.4. Inclusion of sustainability criteria in GI specification

This last part is dedicated to results related to the inclusion of sustainability criteria inside the specification, since it is a highly debated argument, in light of the reform of GI system expected at the end of 2023. It has been observed a trend of an increased inclusion of environmental related aspects inside this specification of GI products (Belletti et al., 2015; Owen et al., 2020; Millet et al., 2020), but their presence is still not high. This trend is not due to policy reasons or regulations but to higher environmental consciousness of producers (Owen et al., 2020). For the agricultural products, some criteria that could be used are related to the variety of plants or their density, as well as rules regarding pest management or weed control or irrigation practices (Belletti et al., 2015). For processed products, the criteria could instead be about the raw materials used or about the production processes. At the European level there was a debate regarding the introduction of sustainability criteria inside the specification of GIs. Belletti et al. (2015) support the voluntary introduction of sustainability criteria inside the specification. Marescotti et al. (2020) instead analyzed the position of different stakeholders, resulting in farmers and national authorities are contrary to the introduction of them inside the specification, while some local actors were instead favorable. Eco-innovations are usually driven mainly by market reasons rather than pure environmental reasons (Owen et al., 2020). For this reason, if there is not any kind of incentive for introducing sustainability criteria producers' organizations are unlikely to introduce them. Narciso and Fonte (2021), also brought up that sustainability criteria should not only be added to the specification but also better communicated to consumers through the label, as discussed in Section 4.

## 4. Discussion and conclusions

Considering the relevance of GIs for the EU agri-food sector and economy and the need to transform the current food system toward a more sustainable one, this study analyzes the role of GI production in the framework of the economic, social and environmental dimensions and of the governance processes. Although social and economic benefits of GIs for producers and territory have already been demonstrated (European Commission, 2021; FAO, 2018b), environmental impacts of GIs and the governance of certified supply food chains are more controversial (Lamarque and Lambin, 2015). More in detail, the methodology that has been designed leverages the results of a systematic literature review in order to map the influence of GIs into the SDGs framework.

A common opinion associates the overall enhancement in resources and environment protection with the adoption of GIs, since these products are generally related to traditional and conscious practices (Narciso and Fonte, 2021). However, a contradictory picture emerges when the effects of GIs on SDGs and relative targets are analyzed in detail. The results of the literature review indicate that it is difficult to evaluate the environmental impacts of the GI certification, since each of them has peculiar characteristics and strong connection with own territory, influencing the externalities on the environment. Moreover, inside the same GI, different management methods (e.g., conventional, organic or integrated production) can be observed (Di Vita et al., 2018), especially if the specification does not impose strict rules. For this reason, also generalization inside the same GI is difficult. Indeed, our results show ambiguous effects, such as opposite outcomes on the environment regarding the same SDG, as summarized in Table 3. For example, for SDG12 GI certification is associated with higher efficiency in the production (e.g., Garcia-Cornejo et al., 2020), while in other (e.g., Bermejo et al., 2021) is associated with lower efficiency. For SDG9, GIs foster innovations through their collective management (e.g., Owen et al., 2020), in other cases they can limit their introduction due to bureaucracy (e.g., Belletti et al., 2015). Also regarding SDG15, GIs can be associated with the conservation of biodiversity (e.g., Bermejo et al., 2021), while in other cases they can privilege on species or variety over others (e.g., Belletti et al., 2015). The specificity of each GI should be considered and the generation of positive or negative externalities should be evaluated case by case. Despite this it was possible to individuate factors that facilitate the presence of positive externalities on the environment: completeness of the specification, producers' environmental consciousness, cooperation and role of institutions, and link with the territory.

GIs were not originally designed to improve environmental sustainability (European Union, 2012). However, through limited modifications, they could have the ambition to become a mark of both authenticity and sustainability, without the necessity of introducing new redundant dedicated marks. In this respect, the new EU reform of GIs regulation is a valuable opportunity, but the paper has highlighted a few conditions not to waste it. Firstly, the current proposal (European Union,

2022) includes the possibility of introducing sustainability criteria inside the specification, yet no details about the type of criteria are given. A few different criteria may be introduced to improve the environmental performances of GIs in manners specific to the different GI products. The introduction of innovations should not be limited by the GI specification, as Belletti et al. (2015); Rabadan et al. (2021) have reported. Eco-innovations such as measures of energy efficiency, better management of the waste produced, or new uses of the final products could be introduced without changing the specifications and the traditional production. One example is the Parmigiano Reggiano PDO case, analyzed by Arfini et al. (2019a), where innovations such as new hygienic rules, new packaging or co-branding were gradually introduced, without interfering with the traditional production processes.

Similarly, there is ambiguity on the process through which producers' organizations may set environmental targets, technological standards, or harmful practices and benchmarks. Indeed, a participatory process, where all the GI system actors are entitled to propose changes in the specification, is a likely solution, as it has been proven to provide benefits for the GI itself (Quiñones-Ruiz et al., 2016). Lastly, introducing sustainability criteria inside the specification is not sufficient to improve environmental sustainability of GIs (Narciso and Fonte, 2021). To make these criteria successful, the four drivers mentioned above have to be taken into consideration.

Environmental consciousness of producers has been shown to lead to better environmental results, (Garcia Cornejo et al., 2020), therefore, the EU proposal should also recommend the implementation of training measures and other information actions for producers, to increase their awareness. Similar actions should be addressed to local institutions, to improve the support they can provide to GI producers. Cooperation and voluntary standards may also be leveraged to a greater extent in order to achieve better environmental sustainability in GI production processes (Owen et al., 2020). To that end, policymakers and economic actors involved in the reform process should consider offering support and guidance to GIs producers that commit to enhancing environmental linkages with the territory of origin through innovations, some of which are mentioned in this paper. The adoption of circular economy principles and the design and implementation of more sustainable material and energy flows inside the producer's organization can be a major way of increasing sustainability of the processes through cooperation. Also, cooperation between producers and research centers or innovative start-ups may be beneficial for the adoption of eco-innovative solutions. The strong connection of GIs with their territory and the practices of environmental sustainability, if already implemented, should also be better communicated to consumers, enhancing the competitiveness of such products. Introducing sustainability criteria inside the specification can be a way for the GI mark to reduce the environmental externalities of the GI production, but also to improve the economic performances, especially in the cases of silent GIs.

The paper has some limitations that open the way to future research. The research leans on a systematic review of pre-existing studies, therefore new qualitative studies of environmental management strategies and operations in real GIs contexts would be an important input to the progress of European GIs reform and regulations. Moreover, it is important to underline that the SDGs analyzed in the present review are only those considered by the reviewed papers. Future works should also address SDGs absent from the extant literature, such as SDG13 and SDG7, to have a complete overview of environmental impacts, and also non-environmental SDG targets. Despite these limitations, in relation to the novelty of the work, the present research contributes to bridge two sides of sustainable development that are only rarely considered jointly in the scientific debate, in spite of their intrinsic links, namely protection of GI products and environmental sustainability. The results of the present research can support decision makers in the agri-food supply chains and food policy domain, as it offers insights on the opportunities to maximize the environmental sustainability of GI food products. According to the discussion of the results, the following future developments can be listed. New qualitative studies of environmental management strategies and operations in real GIs contexts would be an important input to the progress of European GIs reform and regulations. In fact, criteria should be quantifiable and specific for each GIs, taking into consideration each product and territory peculiarity. Dealing with the relationship between GIs and the environment, the Network Analysis can be considered as a method of investigation as already experimented in Beck et al. (2023); Beck and Ferasso (2023). Changing the perspective, the impact of climate changes on GIs products has to be better investigated, since the literature has just started to analyze this issue (Borghini et al., 2023; Salpina and Pagliacci, 2022). Also, the SDGs that have not been analyzed based on the reviewed papers, such as SDG13 or SDG7, have to be investigated to provide a more complete overview. After filling the gaps regarding environmental sustainability analysis of GIs, it is possible to propose a holistic approach that would properly include the three dimensions together, i.e., social, economic and environmental. The role that GI could have in preserving the natural capital and the functionality of ecosystems can promote also strong sustainability practices, instead of the weak ones.

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## CRediT authorship contribution statement

**Silvia Falasco:** Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Paola Caputo:** Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing. **Paola Garrone:** Conceptualization, Methodology, Supervision, Writing – review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

No data was used for the research described in the article.

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## Glossary

*GHG:* Green House Gases
*GI:* Geographical Indication
*PDO:* Protected Designation of Origin
*PGI:* Protected Geographical Indication
*SDGs:* Sustainable Development Goals