„Überall geht ein frühes Ahnen dem späteren Wissen voraus.“

Alexander von Humboldt

Geographic Indications as flagship products for sustainable landscape management in the European Union

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Summary

This Ph.D. thesis addresses the broader topic of sustainable landscape management in European agriculture, with a specific focus on the potential of labeling as a tool contributing to achieving such a goal. The cumulative thesis is composed of four scientific articles that sequentially investigate the potential of food labeling, particularly the Protected Designation of Origin (PDO) label, for promoting sustainable agricultural practices and preserving cultural landscapes. Geographical indications, such as the PDO label, promise to connect agricultural products with the specific landscapes and traditions from which they originate. One key aspect explored in chapters three and four is the correlation between PDO-labeled products and social-ecological indicators in the European Union. Investigations into the role and function of these products within their landscapes highlight benefits for the environmental and cultural maintenance of valuable landscapes. Stakeholder knowledge presented in chapter five reveals insights into the label's potential for the valorization of rural regions and which policy mixes this requires. This thesis concludes that PDO-labeled products have the potential to unify environmental sustainability and social cohesion in rural areas in a synergistic interaction. However, the effective utilization of PDO-labeled products requires a thoughtful mix of policy measures that should be adapted to the different levels of economic success of those products, as well as the conservation requirements of the landscapes around them. Chapter six closes with recommendations for policymakers and stakeholders by discussing how PDO-labeled products can act as flagship products for their respective landscapes, and conflicts that need to be considered when adding sustainability standards to the PDO scheme. Altogether, the research conducted as a part of this thesis shows that geographical indications can be helpful instruments for sustainable landscape management.

Zusammenfassung

Die vorliegende Dissertation befasst sich mit dem allgemeinen Thema der nachhaltigen Landschaftspflege in der europäischen Landwirtschaft, wobei ein besonderer Schwerpunkt auf dem Potenzial der Produktkennzeichnung als Instrument zur Erreichung dieses Ziels liegt. Die kumulative Dissertation besteht aus vier wissenschaftlichen Artikeln, welche aufeinander aufbauend das Potenzial von Lebensmittelkennzeichnung, insbesondere der geschützten Ursprungsbezeichnung (g.U.), für die Förderung nachhaltiger landwirtschaftlicher Praktiken und den Erhalt von Kulturlandschaften untersuchen. Geografische Angaben wie die geschützte Ursprungsbezeichnung versprechen, landwirtschaftliche Produkte mit den spezifischen Landschaften und Traditionen, aus denen sie stammen, zu verbinden. Ein zentraler Aspekt der Arbeit, dargelegt in den Kapiteln drei und vier, ist die Korrelation zwischen den mit dem g.U.-Siegel gekennzeichneten Produkten und den sozial-ökologischen Indikatoren in der Europäischen Union. Durch Untersuchungen zur Rolle und Funktion, die diese Produkte innerhalb ihrer Landschaften haben, werden Vorteile für die ökologische und kulturelle Erhaltung wertvoller Landschaften aufgezeigt. In Kapitel fünf gibt darüber hinaus das Wissen von Stakeholdern Aufschluss über das Potenzial des g.U.-Siegels für die Aufwertung ländlicher Regionen und darüber, welche Policy-Mixe dafür erforderlich sind. Diese Arbeit kommt zu dem Schluss, dass Produkte mit g.U.-Siegel das Potenzial haben, die ökologische Nachhaltigkeit und den sozialen Zusammenhalt in ländlichen Gebieten in einem synergetischen Zusammenspiel zu vereinen. Die erfolgreiche Nutzung von Produkten mit geschützter Ursprungs-bezeichnung erfordert jedoch eine gut ausbalancierte Kombination politischer Maßnahmen, welche an den unterschiedlichen wirtschaftlichen Erfolg der Produkte und die lokalen Erfordernisse des Landschaftsschutzes angepasst sein sollten. Kapitel sechs schließt mit Empfehlungen für politische Entscheidungsträger und Interessenvertreter, indem erörtert wird, wie Produkte mit dem g.U.-Siegel als Aushängeschilder (‚flagship products') für ihre jeweiligen Landschaften fungieren können und welche Konflikte bei der Ergänzung von Nachhaltigkeitsstandards in die g.U.-Richtlinien berücksichtigt werden sollten.

List of abbreviations

CAP	Common Agriculture Policy
EU	European Union
F2F	Farm to Fork strategy
GI	Geographical Indications
HNV-F	High Nature Value Farming
NUTS	Nomenclature of Territorial Units for Statistics
PDO	Protected Designation of Origin
PGI	Protected Geographical Indication
SDGs	Sustainable Development Goals of the United Nations

Remark on the structure

The thesis at hand is submitted as a paper-based (cumulative) dissertation. Therefore, chapters 2-4 are identical to peer-reviewed and published articles in international scientific journals. The titles of the original publications, including the DOI links to the journals' websites, are provided at the beginning of each chapter. Chapter 5 is considered for publication in an international scientific journal as well and is currently under review. Thus, this thesis contains a preprint version of the respective manuscript. Tables and figures hold the number of the corresponding chapter in front of the figure number (e.g., Figure 3.2). In continuous text, references to tables or figures are given by the consecutive numbers used within the respective chapter only (e.g., Fig. 2). Literature references can be found at the end of each chapter separately and appendices to the scientific articles are linked via the publishers' platforms. The spelling of the research articles has been streamlined to American English for their appearance in this thesis. In addition, the text of the published articles was grammatically corrected, but without changing any content or meaning.

Table of Contents

Chapter 1
Introduction to labeling within sustainable landscape management

The sustainability debate with respect to European agriculture landscapes

Sustainability is a multifaceted concept that encompasses economic, social, and environmental considerations. Sustainability is, most basically, described by the notion that any given group should only consume or deplete resources in a way that does not negatively affect the well-being of future generations (Menton et al. 2020, Steffen et al. 2015). In the global sustainability debate, many scholars and practitioners refer to the sustainable development goals (SDGs) of the United Nations. The SDG framework consists of 17 goals and numerous sub-targets that outline how the global society should manage to live within the limits of our planet's resources while ensuring the well-being of everyone (Biermann et al. 2017). These international goals, and the therefrom derived national targets, are increasingly being recognized as a factor in decision-making at various levels, from individual consumption choices to global policy decisions (Biermann et al. 2022). The sustainability debate seeks to consider the impact of our actions on the natural environment and future society. Crucial elements within the sustainability debate are the impact of food production and consumption, and sufficient nutritional provision for all people (Hertel 2015). Besides the obvious necessity of providing enough and healthy food to the population, food production itself is challenged to become more sustainable (Scharlemann et al. 2020), specifically in relation to the social-ecological targets of the SDG framework (Eisenmenger et al. 2020). This entails the current negative trends regarding the transformation of landscapes and ecosystems, soil depletion, freshwater usage, excessive application of chemicals, greenhouse gas emissions, animal welfare, maintenance of food culture, and property rights (Kanter et al. 2018, Oteros-Rozas et al. 2019).

Taking a brief look at the historic development of agriculture during industrialization seems necessary to understand the origin of the common agricultural policy (CAP) in Europe. After the start of the industrialization around the middle of the 19th century, mechanization of agriculture set in. However, it took until the 20th century before the industrialization of the agricultural sector picked up speed (McKittrick 2012). Slowly beginning around 1900, it became increasingly faster after the Second World War. The production of food was transformed from mostly manual tasks and intensive human labor into industrial and market-oriented processes requiring less physical human labor. The agriculture of the pre-industrialized era mainly took place on relatively small scales, often run by families or very small organizational units. With industrialization, however, increasingly large market players, both on the production side and at sales and marketing, began to dominate the agricultural production systems. Mechanization of food production and commodification of food itself led to a vast change in the landscapes and life experiences of millions of people (Peterson et al. 2014, Meeus et al. 1990), starting in Europe and North America. The emergence of mechanization in particular made it attractive for farmers to simplify landscape structures, for example by consolidating land into larger units, removing obstacles for machinery, draining wetlands, keeping wildlife out of agricultural land, and reducing other non-productive landscape structures (Levers et al. 2018, van Vliet et al. 2015). After the European Economic Community (precursor of the EU) was founded in 1957, one of the first common agreements was the 'Common Agriculture Policy', or CAP as it is still called today (European Council 2023). At the time, the main goal of the CAP was to increase food production in a war-torn central Europe and to increase the wages and living standards of farmers and farm workers. Given this historic situation, the benefits of industrialized agricultural production were welcomed and much needed. Since this time, societal needs and political circumstances have changed. Today, the European Union is one of the richest and most prospering regions on the planet, with an oversupply of food, which makes the EU a net exporter of food products (European Commission 2023). The CAP with its supportive measures and policies played an important role in this development. While politics, in general, have drastically changed regarding environmental protection and sustainability goals, most instruments designed for the original goals of the CAP remain in place. This leads to inconsistencies between environmental goals and the allocation

of grants and subsidies, and several scientific studies articulate that the current CAP schemes do not fit the self-imposed sustainability agenda of the European Union (Bouwma et al. 2019, Pe'er et al. 2020).

Focusing on current issues of landscape management, it must be acknowledged that the post-war necessity of ensuring food safety for the continent is no longer of the same outstanding priority. Some of the original policies, some of them in place for decades, are now being criticized as ecologically harmful and contributing to the deterioration of historically grown cultural landscapes (Pe'er et al. 2017, Scown and Nicholas 2020). The scientific evidence for many of those harmful practices has been available for years. For example, the negative impact of conventional agriculture on insects, soil conditions, chemical runoff, and freshwater depletion has been scientifically described (Bieling and Plieninger 2017, Mupepele et al. 2021, Campbell et al. 2017). In contrast to the industrial intensification, there is also an abandonment of agricultural landscapes in remote and less profitable regions, which can also lead to declining biodiversity and loss of socio-cultural values (Rey Benayas et al. 2007). There is an observable structural trend all over Europe showing that during the last decades, the number of small farm businesses decreased constantly, while the average farm size increased. For illustrative purposes: between 2005 and 2020 only farms above 100 ha became more frequent. All farm sizes below this threshold experienced a decline in numbers, with the sharpest loss for the smallest farms, adding up to a loss of 5.3 million farms in total (Eurostat 2022). Furthermore, the number of mixed cropping and mixed livestock farms in the European Union dropped between 2007 and 2020 from around 1.67 million to 0.67 million farms in favor of specialized farms (Eurostat 2023a). These trends are a direct consequence of the intensification and mechanization of industrialized agriculture and eventually lead to a loss of traditional practices and local knowledge regarding landscape management. Despite the theoretical knowledge being available, only relatively recently the European Union launched the so-called 'Green Deal' which is supposed to link economic prosperity and sustainable development on a big scale (European Commission 2019a). A central element of this Green Deal is the 'Farm to Fork' (F2F) strategy (European Commission 2020a), which targets the agricultural sector specifically. It is meant to initiate a sustainable transformation of the European food system in which sustainable landscape management is envisioned to play a key role in this context.

Sustainable landscape management and food labeling

When applying the sustainable development goals (SDGs) of the UN to landscape management, one of the basic rules of the SDGs must be considered: the indivisibility of the goals. In a broader sense, this means that all aspects of sustainable development must be integrated into management decisions regarding landscapes. This holistic approach forms the core idea of sustainable landscape management. To balance both socio-economic and environmental targets, suitable management practices, technology, and policy instruments are needed (Hurni 2000, Plieninger et al. 2020). To date, the CAP still allocates a lot of focus and resources on supporting specialized and intensive agriculture, spending most of the subsidies on purely cost-efficient industrial production with certain minimum standards regarding environmental compliance. To realize sustainable landscape management, there are various approaches. There are purely technical approaches like precision farming, ecological leverage points such as switching away from monocultures, as well as concepts that aim at social and cultural aspects of agricultural production. Examples of the latter include community-supported agriculture, permaculture systems, and re-focusing on traditional agricultural systems (Mann et al. 2018). Many of those social-ecological approaches have in common that their environmental and cultural benefits come along with increased production costs, because of more manual labor, as well as more small-scale and less mechanized production. However, agricultural businesses with more sustainable and less intensive management approaches often do not receive subsidies covering their higher production costs (Henle et al. 2008), which makes the uptake of sustainable practices economically less attractive. Besides CAP subsidies for environmentally friendly practices, producers in these systems also aim to market their products as healthy, high-quality, traditionally produced, or sustainable food and sometimes as geographic specialties (Blanchfield 2000, Asioli et al. 2020). To communicate those product

features to the consumers, labels are the option of choice for many products and brands. To this end, many different labels have been introduced – publicly administered ones as well as labels issued by private initiatives (Ghazoul 2013, Mann and Plieninger 2017).

Labeling food products can, amongst other goals, promote sustainability targets by providing consumers with information about the environmental and social impacts of their purchasing decisions (European Commission 2020c). For instance, labels such as organic, fair trade, and animal welfare seals can help consumers make informed choices about the products they purchase, and to support sustainable production practices (Arfini 2019). By providing this information, labeling can encourage producers to adopt sustainable production practices and can help to increase the demand for sustainable products. This, in turn, can help to promote more sustainable consumption patterns and contribute to the achievement of broader sustainability goals (Sonntag et al. 2023, Meemken et al. 2021). There are many privately issued labels, to the extent that consumer protection agencies warn of label jungles and greenwashing. Meanwhile, there are two time-proven food labels controlled by the EU itself: the organic label, and the geographical indications label. These labels are of almost opposite character (Borrello et al. 2022, Escribano et al. 2020). The organic label requires producers to comply with certain, product-specific, minimum standards, often tied to aspects that are easy to measure or quantify, such as fertilizer application or maximum livestock numbers (European Commission 2019b). On the contrary, the geographic indications (Fig. 1) are awarded to products that are produced in a defined geographical area, according to practices that are related to traditional landscape management and local culture (European Council 1992, Arfini et al. 2019). It is important to note that the legal requirements for geographical indications do not necessarily include sustainability standards or address environmental concerns in their current form. In contrast, other labeling schemes, such as organic certification, animal welfare labels, or sustainability standards, may address specific sustainability issues and provide consumers with more precise information about the environmental or social impacts of their purchasing decisions.

Figure 1.1 The two geographical indication labels issued by the EU. Left: The red and yellow PDO label (Protected Designation of Origin). Right: The blue and yellow PGI label (Protected Geographical Indication). Graphics: https://agriculture.ec.europa.eu.

This Ph.D. project started with the goal of identifying the potential of labeling for products from mosaic landscapes with diverse and extensive use. The research presented in chapter two focuses on agroforestry landscapes and includes various labeling options within an expert-based study (Flinzberger et al. 2020). The experts assessed sustainability indicators for their practicability to be used in labeling schemes and rated different labeling options for their ability to communicate the idea of sustainable landscape management. They came to the common conclusion that among several options the 'geographical indications' would be the most promising 'sustainability label' to represent those cultural landscapes. The advantages they saw in geographical indications over other labeling options were the well-established management at the EU level, as well as the broader focus on traditional landscapes and processing techniques, rather than simplified performance indicators.

Landscape products to promote sustainable practices

Understanding the relationship between agricultural production and cultural landscapes is crucial for understanding the importance of food products stemming from landscape-based value chains in comparison to other types of agricultural products. Cultural landscapes are areas that have been shaped by human activity, which reflects the interaction between people and the natural environment. In Europe, only around 15 % of landcover is classified as unused or abandoned areas. The share of land that has never been used by humans lies well below 10 %, while the share of land that is used for agricultural production (even when completely excluding forest areas) amounts to more than 40 % (Eurostat 2023b, 2023c). Despite the ongoing decrease in rural population, these landscapes host significant social-ecological values and play an important role in preserving cultural traditions, supporting local communities, and promoting sustainable development. It is therefore important to protect cultural landscapes to preserve these social-ecological values and cultural heritages (Brumann and Gfeller 2022, Tieskens et al. 2017, García-Martín et al. 2021). One way to protect cultural landscapes is by promoting landscape-based value chains. Those value chains are based on the production and marketing of products that are linked to specific cultural or – to be more precise – agricultural landscapes. Landscape-based value chains are explicitly suitable entry points for supporting the conservation of cultural landscapes because they can provide income opportunities based on sustainable landscape management (García-Martín et al. 2022). Thus, landscape-based value chains can help to support local economic development and counteract rural outmigration.

High nature value farming (HNV-F) is a landscape classification that is also tightly connected to the maintenance of cultural landscapes. HNV-F refers to farming systems that are characterized by the presence of high levels of biodiversity, as well as cultural landscape values. HNV-F often consists of mosaic-like landscapes providing semi-natural habitats (European Commission 2016, Lomba et al. 2019). Agroforestry landscapes for example, such as the large cork oak (*Quercus suber*) forests and woodlands of the Iberian Peninsula (Fig. 2), are landscapes that combine agriculture and forestry, as well as natural habitats, thereby blending the conservation of biodiversity and sustainable landscape management in a well-balanced way (Plieninger et al. 2015). Further key characteristics of HNV-F systems are extensive landscape management and richness in different structures and habitats. Within these HNV-F landscapes, important ecosystem services such as habitat provision, water retention, and recreational values are maintained, which are provided less in many conventional agricultural systems (Plieninger and Bieling 2013).

Figure 1.2 Mediterranean HNV-F landscapes in the Extremadura (left-hand photo) are archetypical examples of multifunctional landscapes. Especially emblematic are the cork oak forests (right-hand photo) of the Iberian Peninsula which dominate the Spanish Dehesa and Portuguese Montado landscapes.

Based on the findings presented in chapter two, further research focused on the 'Protected Designation of Origin' label (PDO). The first sub-target was to assess the relation between the geographical distribution of PDO-labeled products and landscape characteristics. Focusing on the PDO label as the strongest label among the geographical indications ensured that the research not only covered place-bound traditions and

culture, but also included the production systems themselves. Chapters three and four contain the results of an EU-wide mapping of PDO-labeled products and their spatial correlations with several social-ecological indicators of landscape management. While chapter three presents the overall correlations, it leaves room for speculations about the reasons for the regional differences. Chapter four clarifies which landscapes of certain social-ecological characteristics preferentially produce specific types of PDO-labeled products. A self-created geographical dataset with 638 PDO-labeled products was the foundation of this analysis. The occurrence of PDO-labeled products was statistically related to HNV-F landscapes, agroforestry systems, or similar semi-natural agricultural landscapes as shown in chapter three (Flinzberger et al. 2022b). Deriving policy recommendations from those findings, it appears that HNV-F – which is not yet an official classification in the EU's agricultural policy – could be a useful criterion for certifying sustainable food production (Strohbach et al. 2015). As the results presented in chapters three and four show, geographical indications in general, and the 'Protected Designation of Origin' label (PDO) in particular, are geographically related to several social-ecological indicators that the scientific community associates positively with sustainable landscape management and rural development (Flinzberger et al. 2022b, Flinzberger et al. 2022a). A positive rural development is essential for sustainable landscape management, as the continued presence of people in those areas is a basic requirement for landscape maintenance. The unique position of this label arises from the qualitative descriptions of production techniques and traditional landscape management in its legal texts. This allows the PDO label to cover the landscape-based value chain in its full breadth and depth.

'Protected Designation of Origin' – a gold standard for food landscapes?

The main goals of the PDO label are to provide information to consumers when making distinct purchasing decisions and to support regional production practices by legally protecting the names of local specialties. Furthermore, the label also specifies product traits like ingredients or nutritional values, as well as quality characteristics (Parasecoli 2017, Spiller and Tschofen 2017). For the PDO label as the strictest geographical indication, the whole production process (including the production of raw materials and packaging) must take place within a defined geographical area (European Council 1992). This strict rule makes PDO-labeled products suitable representational items for the cultural landscapes from which they emerge. By recognizing and promoting products that are produced according to traditional methods in specific geographic regions, the PDO label can help preserve traditional ways of landscape management. Geographic labeling of agricultural products is unique in that it not only promotes the labeled product but also promotes the landscape and management practices behind it (Belletti and Marescotti 2011, Bérard and Marchenay 2006). This can include traditional farming and production techniques, as well as the natural resources and biodiversity of the region (Milano and Cazella 2021).

There is some variation in people's knowledge regarding the EU system of geographic indications across Europe, as well as differences in food culture and purchasing patterns when it comes to geographically labeled food versus organically labeled food (Cei et al. 2021). This is likely to be influenced by a range of factors, including the level of awareness, and understanding of the geographical indications scheme (Goudis and Skuras 2021), as well as cultural and economic factors that shaped food consumption patterns over time (Gugerell et al. 2017). In some regions of Europe, there may be stronger traditions of locally produced and traditionally made products, which may be reflected in higher levels of consciousness for geographical indications (Fournier and Michel 2017). As shown in chapter three, there is a significantly higher number of PDO-labeled products in the Mediterranean region, compared to northern and eastern countries of the EU (Flinzberger et al. 2022b). Although not investigated within this thesis, there is the likelihood that those different levels of perception of geographical indications can, in large parts, be explained by regional food culture. In some regions, consumers may be more likely to prioritize geographically labeled products, and willing to pay a premium for them. In other regions, there may be less of a tradition of locally produced and traditionally made products, and therefore lower levels of appreciation for geographical indications. Overall,

it seems that these differences do not reduce the potential of PDO-labeled products to act as representative elements for the sustainable management of 'food landscapes' (García-Martín et al. 2022).

Chapter five provides answers to the question of which framework conditions and policy options are suitable for supporting the PDO as an instrument for sustainable landscape management. It presents outcomes of stakeholder interviews of PDO-producing landscapes in six different regions across Europe. These insights into the product-landscape relationship from the perspective of stakeholders made it possible to identify conditions necessary for maintaining those unique production systems. Most of the suggested policy measures, necessary to utilize PDO-labeled products as tools for making European agriculture more sustainable, are also based on this research. The final discussion in chapter six highlights the potential of PDO-labeled products to act as 'flagship products' of their landscapes of origin in a way that they represent those landscapes and corresponding management practices. It also discusses the chances and challenges of introducing sustainability standards into geographic indication schemes. Furthermore, chapter six offers an outlook on possible future research that emerges from open questions and unexpected outcomes of this thesis.

Methods within this Ph.D. project

The initial research goal of this thesis was to investigate the potential role of product labeling in promoting sustainable landscape management in the European Union. Considering the socio-ecological context in which agricultural production takes place, an adequate mix of methods was necessary to analyze the current state and practical potential of labeling options as policy instruments. While addressing the research questions it was crucial to pay respect to the multi-faceted social-ecological aspects regarding food landscapes. For a cumulative Ph.D. thesis, it is common to combine methods that are not connected to each other, as the scientific articles must stand for themselves during the review processes anyway. This Ph.D. project started with a three-stage Delphi study where experts assessed suitable social-ecological indicators for sustainability labeling and rated different labeling options for their usefulness regarding multifunctional agroforestry systems (Fig 3a). This was followed by a statistical approach based on the mapping of 638 areas of PDO-labeled food products (Fig. 3b). Combined with several social-ecological geographical datasets, different degrees of correlation between PDO production and social-ecological circumstances were calculated. The specific social-ecological datasets were picked based on the experts' opinions on suitable indicators from the first research article. The final step consisted of an investigation of six case study areas from four EU countries (Germany, Greece, Spain, and Portugal), including 46 qualitative interviews with stakeholders of the PDO value chain (Fig. 3c). Those interviews focused on success factors and necessary framework conditions for PDO-labeled products to be successful, their relation to landscape management, and potential future changes to this scheme. Using expert opinions, statistical geography, as well as stakeholder knowledge allowed for picking a suitable labeling strategy for extensively managed landscapes (geographic labels) first, and secondly to assess the aspects of landscape management on which this labeling strategy can have a positive influence.

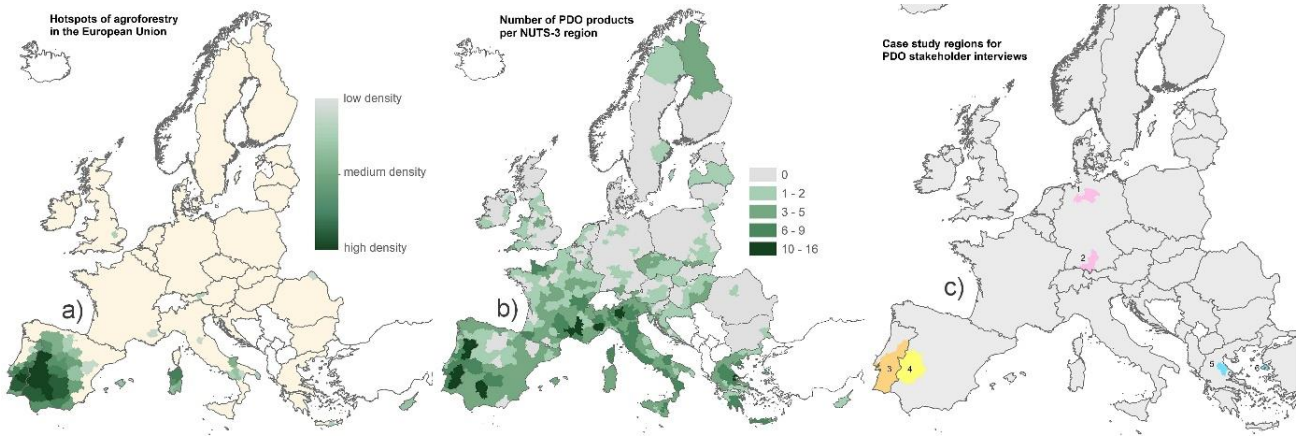

Figure 1.3 The three research phases of this Ph.D. thesis represented by maps. a) The hotspots of agroforestry in the European Union, on which the second chapter focuses with its analysis of labeling options and sustainability indicators. b) The number of PDO-labeled products registered in every NUTS-3 (NUTS = Nomenclature of territorial units for statistics) region of the EU. c) The six case study regions for the stakeholder interviews in PDO-producing regions: 1 – Heath- and peatland Lueneburg / Diepholz (Germany); 2 – Alpine meadows in Allgaeu region (Germany); 3 – Alentejo region (Portugal); 4 – Extremadura region (Spain); 5 – Elassona region (Greece); 6 – Lemnos Island (Greece).

Having started with the expert-based study seems like the best possible choice because the expert knowledge provided the initial spark to investigate the geographical indications in detail. In retrospect, however, it appears sensible as well to collect the impressions and expertise from the on-ground stakeholders earlier in the process. That could have turned the statistical analysis in a slightly different direction, with an increased focus on indicators of rural development, including indicators for the economic success of PDO-labeled products. The decision to go for the statistical-geographical approach first was mainly the consequence of the travel restrictions and lockdown periods caused by the COVID-19 pandemic in 2020 and 2021. Besides this external factor, there is also a practical benefit of interviewing stakeholders in the final step of the project. Because of the expertise and statistical insights gained in the first two phases of the project, it became easier to understand local stakeholders' viewpoints and to address issues that were hidden in the social-ecological data. Bringing this kind of previous knowledge and data-based information to the table, enabled the interviewers to connect with the stakeholders more profoundly by sharing insights from the previous research. During the interviews (chapter five), it became apparent that producers, in particular, expect an interviewer to have in-depth knowledge about the framework of the labeling scheme. Bringing previously acquired knowledge into the interviews made it possible to get into a conversation at eye level and ask about the most relevant details from on-ground practice. If the stakeholder interviews had taken place before the statistical-geographical approach, it would have been beneficial to follow a much more structured interview guideline in order to ensure comparable answers despite lacking background knowledge. Doing it the other way around made it possible to base the interviews on only a few key questions. This left room for a more narrative interview style including personal insights and opinions of the stakeholders. The mix of methods reflects the overall interdisciplinary approach to the topic, which was necessary to grasp the complexity of food systems embedded in cultural landscapes. The involvement of supervisors and co-authors with different backgrounds was the foundation as well as the prerequisite for working on this social-ecological topic. Ecological knowledge helped to ask the right questions about conservation issues to stakeholders and experts, and experience with EU policy frameworks helped to draw useful and applicable conclusions for politics and practice. Finally, the understanding of the landscape as a suitable reference frame for food system research was crucial to combining geographical approaches with social-science interview methods. This way, using the described mix of methods, the complex social-ecological systems of rural areas and agricultural landscapes could be described and researched with the necessary breadth of tools.

References Chapter 1

Arfini F (2019) EU Food Quality Policy: Geographical Indications. In: Dries L, Heijman W, Jongeneel R, Purnhagen K, Wesseler J (eds) EU Bioeconomy Economics and Policies: Volume 2. Palgrave Macmillan, Cham, pp 27–46. 10.1007/978-3-030-28642-2_3

Arfini F, Antonioli F, Donati M, Gorton M, Mancini MC, Tocco B, Veneziani M (2019) Conceptual Framework. In: Arfini F, Bellassen V (eds) Sustainability of European Food Quality Schemes. Multi-Performance, Structure, and Governance of PDO, PGI, and Organic Agri-Food Systems. Springer International Publishing, Cham, pp 3–21. 10.1007/978-3-030-27508-2_1

Asioli D, Aschemann-Witzel J, Nayga RM (2020) Sustainability-Related Food Labels. Annu. Rev. Resour. Econ. 12 (1): 171–185. 10.1146/annurev-resource-100518-094103

Belletti G, Marescotti A (2011) Origin Products, Geographical Indications and Rural Development. In: Sylvander B, Barham E (eds) Labels of origin for food. Local development, global recognition. CABI, Cambridge, pp 75–91

Bérard L, Marchenay P (2006) Local products and geographical indications: taking account of local knowledge and biodiversity. Int Social Science J 58 (187): 109–116. 10.1111/j.1468-2451.2006.00592.x

Bieling C, Plieninger T (2017) The Science and Practice of Landscape Stewardship. Cambridge University Press. Cambridge. 10.1017/9781316499016

Biermann F, Hickmann T, Sénit C-A, Beisheim M, Bernstein S, Chasek P, Grob L, Kim RE, Kotzé LJ, Nilsson M, Ordóñez Llanos A, Okereke C, Pradhan P, Raven R, Sun Y, Vijge MJ, van Vuuren D, Wicke B (2022) Scientific evidence on the political impact of the Sustainable Development Goals. Nat Sustain 5 (9): 795–800. 10.1038/s41893-022-00909-5

Biermann F, Kanie N, Kim RE (2017) Global governance by goal-setting: the novel approach of the UN Sustainable Development Goals. Current Opinion in Environmental Sustainability 26-27: 26–31. 10.1016/j.cosust.2017.01.010

Blanchfield JR (ed) (2000) Food labeling. Woodhead Publishing Limited. Cambridge

Borrello M, Cecchini L, Vecchio R, Caracciolo F, Cembalo L, Torquati B (2022) Agricultural landscape certification as a market-driven tool to reward the provisioning of cultural ecosystem services. Ecological Economics 193: 107286. 10.1016/j.ecolecon.2021.107286

Bouwma I, Zinngrebe Y, Runhaar H (2019) Nature Conservation and Agriculture: Two EU Policy Domains That Finally Meet? In: Dries L, Heijman W, Jongeneel R, Purnhagen K, Wesseler J (eds) EU Bioeconomy Economics and Policies: Volume 2, vol 56. Palgrave Macmillan, Cham, pp 153–175. 10.1007/978-3-030-28642-2_9

Brumann C, Gfeller AÉ (2022) Cultural landscapes and the UNESCO World Heritage List: perpetuating European dominance. International Journal of Heritage Studies 28 (2): 147–162. 10.1080/13527258.2021.1941197

Campbell BM, Beare DJ, Bennett EM, Hall-Spencer JM, Ingram JSI, Jaramillo F, Ortiz R, Ramankutty N, Sayer JA, Shindell D (2017) Agriculture production as a major driver of the Earth system exceeding planetary boundaries. Ecol. Soc. 22 (4). 10.5751/ES-09595-220408

Cei L, Stefani G, Defrancesco E (2021) How do local factors shape the regional adoption of geographical indications in Europe? Evidences from France, Italy and Spain. Food Policy 105: 102170. 10.1016/j.foodpol.2021.102170

Eisenmenger N, Pichler M, Krenmayr N, Noll D, Plank B, Schalmann E, Wandl M-T, Gingrich S (2020) The Sustainable Development Goals prioritize economic growth over sustainable resource use: a critical reflection on the SDGs from a socio-ecological perspective. Sustainability Sci.: 1–10. 10.1007/s11625-020-00813-x

Escribano M, Gaspar P, Mesias FJ (2020) Creating market opportunities in rural areas through the development of a brand that conveys sustainable and environmental values. Journal of Rural Studies 75: 206–215. 10.1016/j.jrurstud.2020.02.002

European Commission (2016) EIP-AGRI Focus Group Sustainable High Nature Value (HNV) farming. Brussels

European Commission (2019a) A European Green Deal. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en. Accessed 11 Oct 2021

European Commission (2019b) Organic farming in the EU. A fast growing sector. Brussels

European Commission (2020a) A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system. Brussels

European Commission (2023) Agri-Food Trade Statistical Factsheet. European Union - Extra EU27. Brussels

European Council (1992) Council Regulation (EEC) No 2081/92. of 14 July 1992 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. Brussels

European Council (2023) Timeline - History of the CAP. https://www.consilium.europa.eu/en/policies/cap-introduction/timeline-history/. Accessed 05 Jul 2023

Eurostat (2022) The evolution of farms and farmland between 2005 and 2020. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_farmland_in_the_European_Union_-_statistics#The_evolution_of_farms_and_farmland_between_2005_and_2020. Accessed 16 Aug 2023

Eurostat (2023a) EU farms: 5.3 million fewer in 2020 than in 2005. https://ec.europa.eu/eurostat/de/web/products-eurostat-news/w/ddn-20230403-2. Accessed 16 Aug 2023

Eurostat (2023b) Land cover statistics in the EU. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Land_cover_statistics#Land_cover_in_the_EU. Accessed 05 Jul 2023

Eurostat (2023c) Land use statistics EU. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Land_use_statistics#Land_use. Accessed 05 Jul 2023

Flinzberger L, Cebrián-Piqueras MA, Peppler-Lisbach C, Zinngrebe Y (2022a) Why Geographical Indications Can Support Sustainable Development in European Agri-Food Landscapes. Front. Conserv. Sci. 2. 10.3389/fcosc.2021.752377

Flinzberger L, Zinngrebe Y, Bugalho MN, Plieninger T (2022b) EU-wide mapping of 'Protected Designations of Origin' food products (PDOs) reveals correlations with social-ecological landscape values. Agron. Sustain. Dev. 42 (3). 10.1007/s13593-022-00778-4

Flinzberger L, Zinngrebe Y, Plieninger T (2020) Labeling in Mediterranean agroforestry landscapes: a Delphi study on relevant sustainability indicators. Sustainability Sci. 15 (5): 1369–1382. 10.1007/s11625-020-00800-2

Fournier L-S, Michel K (2017) Mediterranean Food as Cultural Property? Towards an Anthropology of Geographical Indications. In: May S, Sidali KL, Spiller A, Tschofen B (eds) Taste | Power | Tradition. Göttingen University Press, Göttingen. 10.17875/gup2017-1004

García-Martín M, Huntsinger L, Ibarrola-Rivas MJ, Penker M, D'Ambrosio U, Dimopoulos T, Fernández-Giménez ME, Kizos T, Muñoz-Rojas J, Saito O, Zimmerer KS, Abson DJ, Liu J, Quintas-Soriano C, Sørensen IH, Verburg PH, Plieninger T (2022) Landscape products for sustainable agricultural landscapes. Nat Food 3 (10): 814–821. 10.1038/s43016-022-00612-w

García-Martín M, Quintas-Soriano C, Torralba M, Wolpert F, Plieninger T (2021) Landscape Change in Europe. In: Weith T (ed) Sustainable Land Management in a European Context. A Co-Design Approach, vol 8. Springer International Publishing AG, Cham, pp 17–37. 10.1007/978-3-030-50841-8_2

Ghazoul J (2013) Landscape Labeling: Combining certification with ecosystem service conservation at landscape scales. In: Koellner T (ed) Ecosystem Services and Global Trade of Natural Resources. Routledge, pp 242–261. 10.4324/9780203816639

Goudis A, Skuras D (2021) Consumers' awareness of the EU's protected designations of origin logo. Br. Food J. 123 (13): 1–18. 10.1108/BFJ-02-2020-0156

Gugerell K, Uchiyama Y, Kieninger PR, Penker M, Kajima S, Kohsaka R (2017) Do historical production practices and culinary heritages really matter? Food with protected geographical indications in Japan and Austria. Journal of Ethnic Foods 4 (2): 118–125. 10.1016/j.jef.2017.05.001

Henle K, Alard D, Clitherow J, Cobb P, Firbank L, Kull T, McCracken D, Moritz RF, Niemelä J, Rebane M, Wascher D, Watt A, Young J (2008) Identifying and managing the conflicts between agriculture and biodiversity conservation in Europe–A review. Agriculture, Ecosystems & Environment 124 (1-2): 60–71. 10.1016/j.agee.2007.09.005

Hertel TW (2015) The challenges of sustainably feeding a growing planet. Food Sec. 7 (2): 185–198. 10.1007/s12571-015-0440-2

Hurni H (2000) Assessing sustainable land management (SLM). Agriculture, Ecosystems & Environment 81 (2): 83–92. 10.1016/S0167-8809(00)00182-1

Kanter DR, Musumba M, Wood SL, Palm C, Antle J, Balvanera P, Dale VH, Havlik P, Kline KL, Scholes RJ, Thornton P, Tittonell P, Andelman S (2018) Evaluating agricultural trade-offs in the age of sustainable development. Agric. Syst. 163: 73–88. 10.1016/j.agsy.2016.09.010

Levers C, Müller D, Erb K, Haberl H, Jepsen MR, Metzger MJ, Meyfroidt P, Plieninger T, Plutzar C, Stürck J, Verburg PH, Verkerk PJ, Kuemmerle T (2018) Archetypical patterns and trajectories of land systems in Europe. Reg. Environ. Change 18 (3): 715–732. 10.1007/s10113-015-0907-x

Lomba A, Moreira F, Klimek S, Jongman RHG, Sullivan C, Moran J, Poux X, Honrado JP, Pinto-Correia T, Plieninger T, McCracken DI (2019) Back to the future: rethinking socioecological systems underlying high nature value farmlands. Front. Ecol. Environ. 29: 1006. 10.1002/fee.2116

Mann C, García-Martín M, Raymond CM, Shaw BJ, Plieninger T (2018) The potential for integrated landscape management to fulfil Europe's commitments to the Sustainable Development Goals. Landscape Urban Plann. 177: 75–82. 10.1016/j.landurbplan.2018.04.017

Mann C, Plieninger T (2017) The potential of landscape labeling approaches for integrated landscape management in Europe. Landscape Res. 42 (8): 904–920. 10.1080/01426397.2017.1335863

McKittrick M (2012) Industrial Agriculture. In: McNeill JR, Mauldin ES (eds) A Companion to Global Environmental History, 1. Aufl., vol 55. Wiley-Blackwell, s.l., pp 411–432. 10.1002/9781118279519.ch23

Meemken E-M, Barrett CB, Michelson HC, Qaim M, Reardon T, Sellare J (2021) Sustainability standards in global agrifood supply chains. Nat. Food. 10.1038/s43016-021-00360-3

Meeus J, Wijermans MP, Vroom MJ (1990) Agricultural landscapes in Europe and their transformation. Landscape and Urban Planning 18 (3-4): 289–352. 10.1016/0169-2046(90)90016-U

Menton M, Larrea C, Latorre S, Martinez-Alier J, Peck M, Temper L, Walter M (2020) Environmental justice and the SDGs: from synergies to gaps and contradictions. Sustainability Sci. 10.1007/s11625-020-00789-8

Milano MZ, Cazella AA (2021) Environmental effects of geographical indications and their influential factors: A review of the empirical evidence. Current Research in Environmental Sustainability 3: 100096. 10.1016/j.crsust.2021.100096

Mupepele A-C, Bruelheide H, Brühl C, Dauber J, Fenske M, Freibauer A, Gerowitt B, Krüß A, Lakner S, Plieninger T, Potthast T, Schlacke S, Seppelt R, Stützel H, Weisser W, Wägele W, Böhning-Gaese K, Klein A-M (2021) Biodiversity in European agricultural landscapes: transformative societal changes needed. Trends in ecology & evolution. 10.1016/j.tree.2021.08.014

Oteros-Rozas E, Ruiz-Almeida A, Aguado M, González JA, Rivera-Ferre MG (2019) A social-ecological analysis of the global agrifood system. PNAS. 10.1073/pnas.1912710116

Parasecoli F (2017) Geographical Indications, Intellectual Property and the Global Market. In: May S, Sidali KL, Spiller A, Tschofen B (eds) Taste | Power | Tradition. Göttingen University Press, Göttingen

Pe'er G, Bonn A, Bruelheide H, Dieker P, Eisenhauer N, Feindt PH, Hagedorn G, Hansjürgens B, Herzon I, Lomba Â, Marquard E, Moreira F, Nitsch H, Oppermann R, Perino A, Röder N, Schleyer C, Schindler S, Wolf C, Zinngrebe Y, Lakner S (2020) Action needed for the EU Common Agricultural Policy to address sustainability challenges. People Nat. 10.1002/pan3.10080

Pe'er G, Lakner S, Müller R, Passoni G, Bontzorlos V, Clough D, Moreira F, Azam C, Berger J, Bezak P, Bonn A, Hansjürgens B, Hartmann L, Kleemann J, Lomba A, Sahrbacher A,

Schindler S, Schleyer C, Schmidt J, Schüler S, Sirami C, Meyer-Höfer M von, **Zinngrebe Y** (2017) Is the CAP fit for purpose? An evidence-based fitness check assessment. Leipzig

Peterson JM, Caldas MM, Bergtold JS, Sturm BS, Graves RW, Earnhart D, Hanley EA, Brown JC (2014) Economic linkages to changing landscapes. Environmental management 53 (1): 55–66. 10.1007/s00267-013-0116-7

Plieninger T, Bieling C (2013) Resilience-Based Perspectives to Guiding High-Nature-Value Farmland through Socioeconomic Change. Ecol. Soc. 18 (4). 10.5751/ES-05877-180420

Plieninger T, Bieling C, Fagerholm N, Byg A, Hartel T, Hurley P, López-Santiago CA, Nagabhatla N, Oteros-Rozas E, Raymond CM, van der Horst D, Huntsinger L (2015) The role of cultural ecosystem services in landscape management and planning. Current Opinion in Environmental Sustainability 14: 28–33. 10.1016/j.cosust.2015.02.006

Plieninger T, Muñoz-Rojas J, Buck LE, Scherr SJ (2020) Agroforestry for sustainable landscape management. Sustain Sci 15 (5): 1255–1266. 10.1007/s11625-020-00836-4

(2020b) Report from the Comission to the European Parliament and the Council. regarding the use of additional forms of expression and presentation of the nutrition declaration. Brussels

Rey Benayas JM, Martins A, Nicolau JM, Schulz JJ (2007) Abandonment of agricultural land: an overview of drivers and consequences. CABI Reviews 2007. 10.1079/PAVSNNR20072057

Scharlemann JPW, Brock RC, Balfour N, Brown C, Burgess ND, Guth MK, Ingram DJ, Lane R, Martin JGC, Wicander S, Kapos V (2020) Towards understanding interactions between Sustainable Development Goals: the role of environment–human linkages. Sustainability Sci. 15 (6): 1573–1584. 10.1007/s11625-020-00799-6

Scown MW, Nicholas KA (2020) European agricultural policy requires a stronger performance framework to achieve the Sustainable Development Goals. Global Sustainability 3. 10.1017/sus.2020.5

Sonntag WI, Lemken D, Spiller A, Schulze M (2023) Welcome to the (label) jungle? Analyzing how consumers deal with intra-sustainability label trade-offs on food. Food Quality and Preference 104: 104746. 10.1016/j.foodqual.2022.104746

Spiller A, Tschofen B (2017) Taste – Power – Tradition. Placing Geographical Indications on an Interdisciplinary Agenda. In: May S, Sidali KL, Spiller A, Tschofen B (eds) Taste | Power | Tradition. Göttingen University Press, Göttingen. 10.17875/gup2017-1004

Steffen W, Richardson K, Rockström J, Cornell SE, Fetzer I, Bennett EM, Biggs R, Carpenter SR, Vries W de, **Wit CA** de, **Folke C, Gerten D, Heinke J, Mace GM, Persson LM, Ramanathan V, Reyers B, Sörlin S** (2015) Sustainability. Planetary boundaries: guiding human development on a changing planet. Science (New York, N.Y.) 347 (6223): 1259855. 10.1126/science.1259855

Strohbach MW, Kohler ML, Dauber J, Klimek S (2015) High Nature Value farming: From indication to conservation. Ecological Indicators 57: 557–563. 10.1016/j.ecolind.2015.05.021

Tieskens KF, Schulp CJ, Levers C, Lieskovský J, Kuemmerle T, Plieninger T, Verburg PH (2017) Characterizing European cultural landscapes: Accounting for structure, management intensity and value of agricultural and forest landscapes. Land Use Policy 62: 29–39. 10.1016/j.landusepol.2016.12.001

van Vliet J, Groot HL de, **Rietveld P, Verburg PH** (2015) Manifestations and underlying drivers of agricultural land use change in Europe. Landscape Urban Plann. 133: 24–36. 10.1016/j.landurbplan.2014.09.001

Chapter 2
Sustainability indicators for labeling landscape products

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Abstract

In the face of unsustainable land-use changes including intensified production and abandonment, agroforestry systems have the potential to support a diversity of social and ecological functions in agricultural landscapes. Mediterranean agroforestry landscapes have been conserved through traditional practices mostly embedded in small-scale, family businesses. Production labels bear the opportunity to indicate sustainable management along the supply chain and at the same time generate higher incomes for sustainably producing farms. We used an expert-based Delphi survey with three rounds of questions to analyze i) the relevance of different sustainability aspects in agroforestry systems, ii) the suitability of derived indicators for labeling, and iii) the specific potentials and barriers for labeling agroforestry production systems.

The results show that 12 of 17 sustainability aspects – each linked to one of the UN Sustainable Development Goals (SDGs) – are considered relevant for agroforestry systems, representing social-ecological and economic interests in a balanced way. Translating those goals into suitable indicators is the more challenging step, revealing the lack of appropriate data, the complexity of sustainability challenges, and a low willingness for producers to adapt their practices as key limiting factors. The assessment of the labeling schemes indicated coherent responses despite the diverse backgrounds of participants. Alongside eco-labels and social labels, geographical indications were suggested as the most suitable options for the agroforestry context, despite them not being invented to reflect sustainability in the first place. Although experts are highly aware of the social-cultural values of agroforestry systems, they see little potential to use those social-cultural aspects for labeling agroforestry products. Initial costs and missing consumer awareness for agroforestry are major reasons for not joining labeling schemes. We discuss the possibility of an agroforestry label and why elements of geographical indication labels may fit well for this purpose.

2.1 Introduction

Agricultural landscapes face various social-ecological challenges, with intensification, scale enlargement, and land abandonment being the most dominant – and often non-sustainable – development processes. Intensification can have consequences such as reduced soil conservation (Lorenz and Lal 2014), higher greenhouse gas emissions (Aertsens et al. 2013), and higher water demands (Camilli et al. 2018). Abandonment, on the other side, leads to reduced production capacities in rural landscapes (Hertel 2015), losses of cultural values of landscapes (Costa et al. 2014, Costa et al. 2011), and reduced agrobiodiversity (Mosquera-Losada et al. 2018, Bugalho et al. 2011). To guide society towards sustainability, the United Nations has released the Sustainable Development Goals (SDGs) that emphasize the indivisibility of biological conservation, health, well-being, economic innovation, and other goals. While these goals outline an ambitious pathway to a more sustainable society, currently prevalent forms of agriculture and agricultural policy conflict with a number of SDGs (Mann et al. 2018, Kanter et al. 2018). For example, the rules of the EU Common Agriculture Policy do not provide an effective contribution to the SDGs (Pe'er et al. 2019). It performs especially weak regarding SDGs such as "clean water" or "life on land" (Pe'er et al. 2017). Given that climate change impacts like water scarcity or wildfires will be of particular severity in the Mediterranean region, alternative approaches are needed to preserve social-ecological functions embedded in agricultural

landscapes (Malek et al. 2018). Thus, reversing the current trajectory of non-sustainable intensification and promoting more resilient agricultural practices is long overdue.

Sustainability of agroforestry systems

One strategy to facilitate a transition of agricultural systems towards better coverage of the SDGs is agroforestry – a land-use practice that has been reported to provide synergies between different dimensions of sustainability and between multiple ecosystem services (Campos et al. 2019, Mosquera-Losada et al. 2018, Jose 2009). Previous studies showed that AFS often support high biodiversity (Torralba et al. 2016), are effective in tackling climate change (Mosquera-Losada et al. 2018, Montagnini 2017, Lin 2011), and can transmit high values of cultural identification and well-being (Moreno et al. 2018, Plieninger and Huntsinger 2018). One global hotspot of agroforestry is the Mediterranean region (den Herder et al. 2017, Malek and Verburg 2017). Mediterranean agroforestry landscapes were formed through a long tradition of human maintenance, partly since pre-Roman times (Aronson et al. 2009). By that, they form cultural landscapes that are part of a rural cultural heritage (Torralba et al. 2018b) and have intrinsic aesthetic values (Torralba et al. 2018a). They are often perceived as natural, while factually they are based on well-balanced practices of extensive management (Huntsinger and Oviedo 2014). While scientific literature has highlighted the various ecosystem services from AFS, current agriculture policies do not show awareness for the societal value of agroforestry (Santiago-Freijanes et al. 2018a, Santiago-Freijanes et al. 2018b, Pisanelli et al. 2014). Thus, subsidies and market changes have decreased the economic profitability of agroforestry, led to land use polarization, and endangered the social-ecological integrity of Mediterranean AFS (Escribano et al. 2018, Hartel and Plieninger 2014).

Potentials and barriers of labeling in multifunctional landscapes

Agroforestry needs viable economic approaches and profitability in order to withstand current trajectories of land abandonment and intensification while maintaining, developing, and revitalizing sustainable land management practices around traditional agroforestry. The potential of labeled agroforestry systems (AFS) to strengthen the SDG agenda has not been explored in detail yet. While the general benefits of labeling have been theoretically described and demonstrated in various case studies (OECD 2016), there are no specific labels for products from agroforestry. Typical problems for product labeling in agroforestry are initial and ongoing costs for implementation and marketing (Tscharntke et al. 2015), a lack of distribution channels and adequate market infrastructure (Mann and Plieninger 2017), a lack of consumer awareness, missing price premiums (Horrillo et al. 2016), and the technical issues of complying with and monitoring of label standards (Mann et al. 2018). Furthermore, it is challenging to define applicable (producer side) and understandable (consumer side) indicators for monitoring and marketing that clearly relate to agroforestry features and the SDGs in a broad sense.

While a number of labels and certificates focus on single aspects of land use (e.g., organic production practices, animal welfare standards, GMO-free food), labels referring to multifunctional land management practices, such as agroforestry, are scant. So far, only a few researchers have addressed agroforestry-specific labeling (Escribano et al. 2018). Common forestry labels like FSC or PEFC have only started to include specific standards for some forms of agroforestry (in particular, for cork production), but do not use the term "agroforestry" in their labels (Masiero et al. 2011, Dias et al. 2015). Food labels so far do not explicitly highlight agroforestry, although many food products are strongly linked with AFS like orchard meadow fruits, olive oil, or Iberian ham (Herzog 1998, Egea and Pérez y Pérez 2016, Mann and Plieninger 2017). Although agroforestry labels are currently almost non-existent, the potential to include agroforestry systems into sustainability labels is high, as AFS often represent biodiversity-rich as well as culturally valuable landscapes, and are based on sustainable management practices (Elevitch et al. 2018).

Research questions

In this study, the potential of sustainability labeling for supporting Mediterranean AFS is analyzed by asking the following key questions: i) Which aspects of sustainability are considered relevant for agroforestry production systems, and which indicators can represent the respective aspects? ii) Which label types can indicate the relevant sustainability aspects from producers to consumers in a comprehensive and understandable way? iii) Which potentials do agroforestry-related labels have and which barriers to implementation or communication do they face?

The next section presents the intermediate steps of the expert-based Delphi methodology adjusted to the analysis of Mediterranean AFS. Subsequently, results are displayed in response to the three research questions leading to a synthesized assessment of relevant sustainability indicators. Section four discusses the possibilities of agroforestry-specific indicators and the potential role of geographical indications in agroforestry labeling, leading to final conclusions.

2.2 Method

The Delphi approach

We carried out a Delphi survey in the form of a three-round online questionnaire among agroforestry experts. By facilitating a consensus process among participants, the Delphi technique helped us to identify common opinions and iteratively let the participants assess those findings. We constructed our Delphi survey as a mix of the 'decision' and 'scenario' Delphi according to the typology by Mukherjee et al. (2015). With the multi-round approach, we were able to feed intermediate results back into the survey in an anonymized way. A similar Delphi method has been used by Escribano et al. (2018) for finding sustainability indicators for dehesa agroforestry farms. While the latter study focused more on a consensus approach by repeating the same questions, we carried out a scoping-like Delphi survey where the different rounds built upon each other, leading to a collective opinion on the topic (Horrillo et al. 2016). Anonymous feedback enabled us to share information with the participants without risking any self-censoring due to societal expectations.

Sampling

Following Hasson et al. (2000) we conducted a purposive sampling in which we "hand-picked" and invited experts with professional and/or academic backgrounds in Mediterranean AFS. In the beginning, we addressed potential participants through agroforestry research and practice networks (EURAF, AGFORWARD, AFINET, and EIP AGRI) and asked them to suggest further colleagues or collaborators. In this way, we finally invited 48 selected experts to the first survey round. The list of participants consisted of scientists, institutional and private researchers, and scientifically trained practice partners from the fields of agroforestry and labeling. Finally, 23 respondents answered the first round of our survey, 18 respondents completed the second round, and 13 respondents answered the questionnaire in the final round. Experience from other Delphi studies shows that this method is useful for eliciting judgments from expert respondents even when achieving only small sample sizes. Our respondent numbers were similar to the median value of 20 respondents (according to the review of 49 Delphi studies by (Mukherjee et al. 2018).

Within the 23 respondents that completed the first round, we found three groups: 10 senior academics (age 40+ and/or 20+ years of experience), 4 junior academics (younger and less experienced researchers affiliated with universities), and 9 non-academic respondents (currently not working at a university).

Survey design and implementation

In our three-round survey, we included ranking, rating, and free listing tasks, as well as questions about potentials, barriers, and predictions for future development. Figure 1 shows a flow chart of the main ranking and rating tasks in all three survey rounds. Throughout the survey, we followed three lines of interest (see three columns within the flow chart), that were coherent with our research questions: i) aspects and indicators; ii) labeling options in AFS, and iii) potentials and barriers for labeling in agroforestry.

We gave feedback in between the different survey rounds in the form of a brief descriptive summary of the previous round. Therefore, we provided the rankings and Likert ratings of the sustainability aspects and the labeling options. Except for one question, all Likert scales ranged from one to five (zero for now answer), and for the ranking tasks we assigned the highest scores to the top-ranked items and vice versa (e.g., for the 12-item ranking, the top item received 12 points, the lowest item received one point, items not ranked received no points). Before inviting the participants to the surveys, we pre-tested the survey structure and the clarity of the questions with colleagues experienced in agroforestry, sustainability, or labeling.

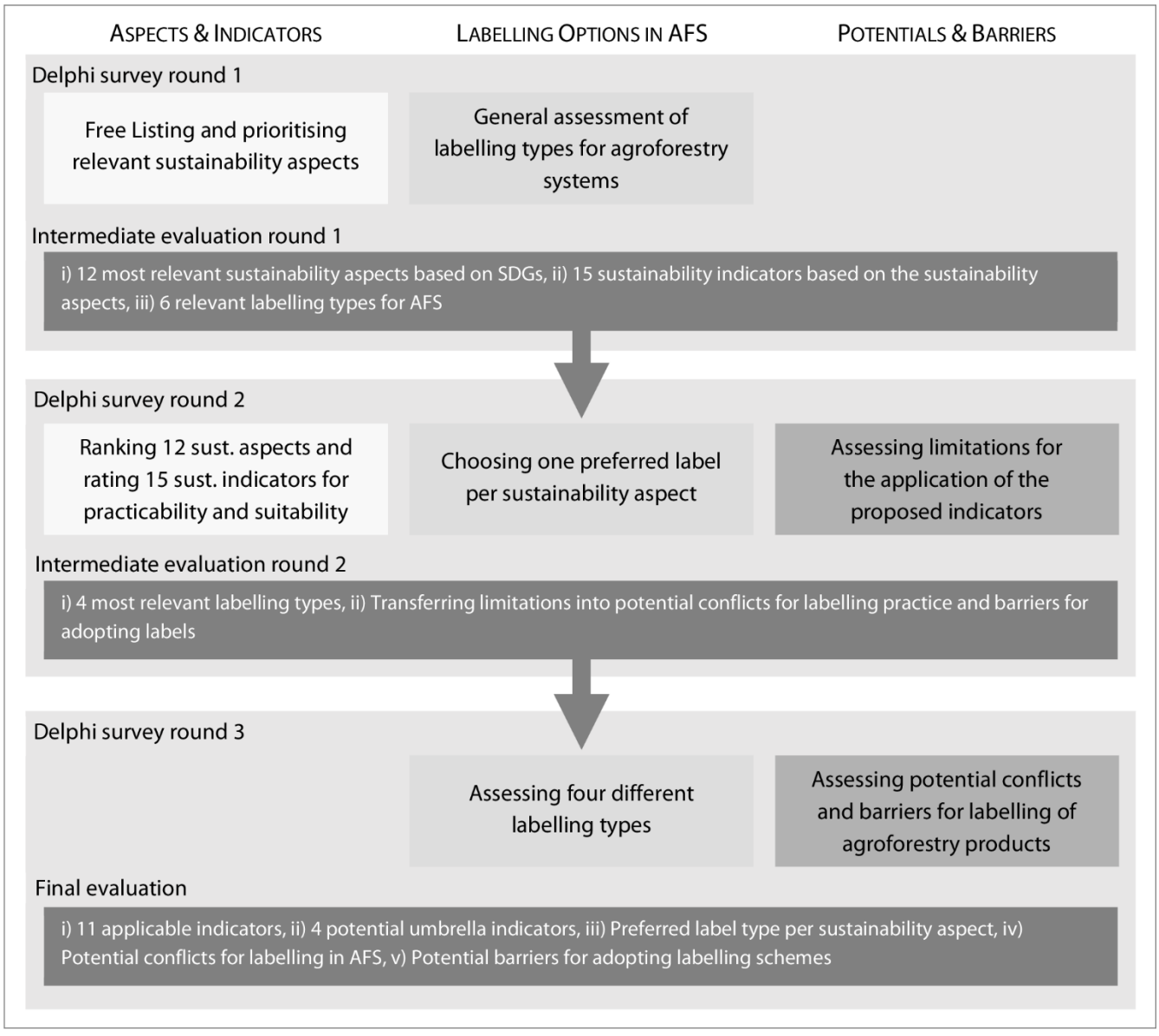

Figure 2.1 The flow chart presents the central tasks that the survey participants carried out and the intermediate evaluation steps we did in order to create an input for the subsequent rounds.

To have a starting point for finding a consensus on relevant sustainability indicators for AFS we scanned relevant literature and consulted the SDGs. Additionally, from the literature, we extracted a list of aspects that reflect the concept of sustainability in general or for agroforestry in particular (Escribano et al. 2018, Pollastrini et al. 2018, Nair and Toth 2016). To cover sustainability in all its facets we derived one agroforestry-specific sustainability aspect from each of the 17 SDGs. During the first survey round the participants ranked those 17 sustainability aspects three times for i) their ability to represent sustainable management, ii) for their applicability for monitoring, and iii) for their potential to be communicated to consumers. The respondents added more aspects during a free listing task. Further, they also ranked a list of nine given labeling or certification types three times for their suitability regarding sustainable landscape management, technical implementation, and communicating sustainability. Besides this, we asked the participants for demographic data, about AFS and products they are familiar with, and for a general assessment of the current state of sustainability in agroforestry.

During the first intermediate step, we condensed a 17-item list of SDG-based sustainability aspects into a 12-item list of relevant aspects. For processing the free listing answers of sustainability aspects, we aggregated 18 categories of sustainability aspects from the free listing and chose the nine most frequently mentioned categories. The ranking task of the SDG-based aspects also yielded nine high-ranked aspects. Five of the nine free listing aspects were similar to the SDG-based aspects. Thus, we obtained a list of the 12 most relevant sustainability aspects (Table 1). SDGs number two (no poverty), five (gender equality), seven (clean energy), eleven (sustainable cities) and fourteen (life below water) dropped out due to the low ranking of the suitability in the context of agroforestry. From the ranking of the labels and certifications, we extracted six relevant items.

Based on the 12 sustainability aspects, we defined 15 sustainability indicators for agroforestry contexts, which we then introduced during the second round (Table 1). As the main criteria for choosing an indicator, we looked for i) easy determination of a value/answer, ii) high level of representation of agroforestry landscape issues, and iii) credibility of the indicator (van Oudenhoven et al. 2018). For three sustainability aspects, we found two equally sensible but technically different indicators that we included both. Thus, in round two we presented 15 indicators for 12 sustainability aspects to the respondents.

During the second survey round the participants again ranked the 12 sustainability aspects twice. Once, for how well the aspect can be supported by labeling an agroforestry product, and second, for how well it could be supported by labeling the landscape management. Further, they chose their preferred label type for each of the 12 sustainability aspects, gave Likert ratings to the 15 sustainability indicators for practical applicability and consumers' understanding, and selected limiting factors for applying the indicators.

For round three, we extracted the three most relevant labeling types from a choice task in round two where the respondents stated their preferred label for each sustainability aspect. As we added a hypothetical fourth option of an 'agroforestry label', the respondents had to assess four different labeling options regarding four different qualities: i) introducing and guaranteeing standards; ii) having trade-offs or conflicts; iii) producers' identification with the label, and iv) consumers' understanding of the label. Finally, in our last round of the Delphi survey, we asked the participants to rate four potential conflicts that could occur around labeling agroforestry products, and we asked them for the most likely barriers that could hinder the adoption of labeling standards.

Table 2.1 From free listing and ranking in the first Delphi round, 12 relevant sustainability aspects were defined (left column). Subsequently, 15 corresponding sustainability indicators (right column) were proposed.

12 Relevant sustainability aspects	15 Corresponding indicators
Income and social coherence from agroforestry	Salaries paid to farmworkers compared to national median income [%]
Improved quality of rural living conditions	Paid vacation [days/year]
Efficient use of natural resources (including water and soil)	Availability of an environmental management plan (erosion, pollution, resource depletion, etc.) [Yes/No]
Diversification, innovation, and resilience in agroforestry systems	Share of revenues from direct sales & local markets [%]
Structural and functional biodiversity	a) Share of the area set aside for natural vegetation areas [%] b) Abundance of registered bird species [number of birds]
Training and education on agroforestry	Training days for workers on sustainability practices, techniques, and tools [days/year]
Climate-smart agriculture (mitigation and adaption)	a) Trees per area [No of Trees/ha] b) Renewable energy consumption [%]
Integrated pest and fertilizer management	No chemical fertilizers and pesticides [Yes/No]
Stakeholder/community participation & empowerment	Access to knowledge networks for farmers [Yes/No]
Maintenance of cultural heritage and social networks	Use of cultural landscape characteristics or local traditions for marketing [Yes/No]
Availability of financing options (e.g. farm income, loans, subsidies)	a) Share of revenues that stays with producer [%] b) Share of revenues, compensating for ES provision [%]
Support for sustainable production infrastructure	Involved in local/regional planning processes [Yes/No]

2.3 Results

General information

The participants stated to be familiar with various types of agroforestry and different agroforestry products. Table 2 shows the more and less commonly known agroforestry types and products among the respondents:

Table 2.2 Number of respondents that stated to be familiar with the following...

...Agroforestry systems	n	%	...Agroforestry products	n	%
Silvopastoralism	14	61	Tree crops	18	78
Silvoarable lands	9	39	Food crops	14	61
Multi-purpose hedgerows	5	22	Timber	12	52
Short-rotation plantation	4	17	Services (e.g. tourism, recreation)	12	52
Alley cropping	8	35	Fodder crops	10	43
Windbreaks	3	13	Food products from animals	8	35
Mixed farming systems	9	39	Wooden or plant-based fuel	8	35
			Cork	6	26
			Non-food products from animals	2	9
			Other	2	9

Initially, they valued the current sustainability of agroforestry management relatively high at 3.86 (out of 5) with a standard deviation of 0.68. The general economic importance of labeling for AFS was rated at 3.48 (out of 5) and similarly, the potentially positive influence of labeling on the sustainability of AFS was rated at 3.83 (out of 5). Both ratings had a larger standard deviation (1.35, respectively 1.11) than for the question on current sustainability, showing more diverging views on the latter two questions.

Sustainability aspects and indicators

During round two the 12 relevant sustainability aspects were ranked again twice for their suitability for i) labeling agroforestry products, and ii) labeling agroforestry landscape management (Table 3). The efficient use of resources was ranked most suitable in both cases and also climate-smart agriculture, biodiversity, diversification, and rural livelihood were ranked relatively high. The two rankings yielded mostly congruent results. Only for income and sustainable fertilizer management experts ranked the suitability for product labeling much higher than for landscape labeling and vice versa, biodiversity was ranked more suitable for landscape labeling. Further, the participants rated 15 sustainability indicators for their suitability regarding practical applicability and consumers' understanding. In Table 3 we present three color-coded classes of indicators' suitability, which are green for usable indicators, yellow for usable indicators with minor restrictions, and red for indicators that based on experts' assessment cannot be recommended for use. In addition to the color coding, the text within this field briefly describes the restrictions. Type, form, and duration of land ownership were suggested as additional suitable indicators in the free text section of round three, referring to contract duration and whether compensation for investments during the contract time exists.

Labeling in agroforestry – potentials and barriers

When choosing their preferred label type for improving each sustainability aspect (Table 4), we found without surprise that for environmental aspects the experts dominantly chose eco-labels (chosen for five aspects), and regarding the social and economic aspects they mainly opted for social labels (chosen for four aspects). For two aspects, related to cultural heritage and access to finance, the respondents chose protected geographical indication labels as the optimal representation. For the sustainability aspect representing SGD number 16, the participants suggested process and production audits. The fact that eco-labels were chosen most often is in line with the high rating for their comprehensiveness (4.11 out of 5 Likert points). In addition, eco-labels were chosen for the sustainability aspects with the highest relative rankings. This correlation of relative ranking of the aspect and rating for comprehensiveness appears less clearly for 'social & fair-trade labels' which received 3.0 points for comprehensiveness and were assigned to the medium ranked aspects, while 'labels for geographic origin' (GIs) which were suggested for the lowest-ranked aspects got 3.12 points for comprehensiveness. Further, we found no patterns regarding the choice of labels when looking at the rating for applicability or understanding of the respective sustainability indicator. Similarly, the different factors that limit the indicators' application appear not to be related to certain label types in particular.

Table 2.3 Summary of the key results of the first research question presenting the relevant sustainability aspects (based on SDGs) with their rankings for their suitability with regard to product labeling or landscape labeling. Further, it shows the ratings for each sustainability indicator and a recommendation for potential application. The indicator ratings are color-coded as follows: green=rating above median value; yellow=rating below median but above 10th percentile; red=rating below 10th percentile. Indicator classification: green=usable indicators; yellow=usable with minor restrictions; red=not recommended to use.

SDG	Sustainability aspect for AFS	Aspects' suitability for product labelling	Aspects' suitability for landscape labelling	Sustainability indicator for AFS	Ranking for indicators' applicability	Ranking for indicators' understanding	Classification of indicators' suitability
1 NO POVERTY	Income & social coherence from agroforestry	4	9	Salaries paid to farmworkers	4.00	4.11	Applicable and understandable
3 GOOD HEALTH AND WELL-BEING	Improved quality of rural living conditions	5	4	Paid vacation days	3.18	3.65	Understandable but problematic applicability
4 QUALITY EDUCATION	Education & knowledge on sustainable agroforestry	9	6	Training-days on sustainability practices	3.67	2.88	Applicable but problematic understanding
6 CLEAN WATER AND SANITATION	Sustainable pest & fertilizer management	6	12	No chemical fertilizers and pesticides	4.18	4.56	Applicable and understandable
8 DECENT WORK AND ECONOMIC GROWTH	Diversification & innovation for competitive agroforestry farms	2	5	Revenues from direct sales	3.06	3.00	Critical applicability
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Cultural heritage & social networks	12	11	Use of cultural landscape characteristics for marketing	3.50	3.50	Applicable and understandable
10 REDUCED INEQUALITIES	Access to financing options	10	9	Final revenues for producer	3.25	3.41	Understandable but problematic applicability
10 REDUCED INEQUALITIES				Revenues, compensating for ES provision	3.56	3.00	Applicable but problematic understanding
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Efficient use of natural resources	1	1	Availability of environmental management plan	4.22	3.35	Applicable but problematic understanding
13 CLIMATE ACTION	Climate-smart agriculture	3	3	Number of trees per area	3.35	3.83	Understandable but problematic applicability
13 CLIMATE ACTION				Renewable energy consumption	3.18	3.56	Understandable but problematic applicability
15 LIFE ON LAND	Structural and functional biodiversity	7	2	Area set aside for natural vegetation	4.00	3.56	Applicable and understandable
15 LIFE ON LAND				Registered bird species	2.81	3.56	Critical applicability
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	Support for sustainable production infrastructure	11	7	Involvement in landscape planning processes	3.50	2.72	Critical understanding
17 PARTNERSHIPS FOR THE GOALS	Community participation & stakeholder empowerment	8	8	Access to knowledge networks	3.83	2.78	Critical understanding

Table 2.4 Labeling types that were suggested most frequently as suitable to improve the respective sustainability aspect. Column two shows the label type that experts suggested. Column three shows the frequency (n) of suggestions among all 18 respondents of Delphi round two.

12 Relevant sustainability aspects	Label type suggested by experts	Frequency n out of 18
Income & social coherence from agroforestry	Social & fair-trade labels	14
Improved quality of rural living conditions	Social & fair-trade labels	12
Education & knowledge on sustainable agroforestry	Social & fair-trade labels	7
Sustainable pest & fertilizer management	Eco-labels	12
Diversification & innovation for competitive agroforestry farms	Eco-labels	9
Cultural heritage & social networks	Geographic indication labels	8
Access to financing options	Geographic indication labels	7
Efficient use of natural resources	Eco-labels	14
Climate-smart agriculture	Eco-labels	9
Structural and functional biodiversity	Eco-labels	15
Support for sustainable production infrastructure	Production and process audits	6
Community participation & stakeholder empowerment	Social & fair-trade labels	11

Four selected labels were rated according to four different questions during round three (Figure 2). In all four questions, GIs received the best rating and 'controlled eco-labels' the second-best. While the hypothetical agroforestry label was rated as the third-best option regarding 'potential conflicts or trade-offs' and 'producers' identification' with the label, it came last for 'easiness to introduce and guarantee the standard' and for 'consumers' understanding'. Surprisingly the 'social and fair-trade labels' received the lowest rating regarding the 'potential conflicts or trade-offs' and for the 'producers' identification'.

In our second survey round, we asked for the most limiting factors for the implementation of each indicator and counted the two most frequently mentioned ones as relevant. For 87% of all indicators, experts mentioned a lack of valid data as the main limiting factor, followed by the lack of willingness of producers (for 60% of all indicators), a lack of expertise for monitoring (40%) as well as problematic policies or land tenure (27%).

In round three we asked them to rate five potential barriers that keep farmers or land managers from joining labeling schemes, offering the options of "not a barrier" (zero), "maybe a barrier" (1), and "surely a barrier" (2). Here, the biggest barriers appeared to be the initial costs of certification with a rating of 1.71 (out of 2), and the time requirement for farmers (1.64). The necessary compliance with rules and the problem of finding no final market (both at 1.50) were also considered relevant barriers while missing economic benefits, with a rating of 1.21, was not. Additional barriers, both mentioned two times by the participants, were the long-

term fees for certification schemes that maybe will not pay off, as well as policy issues – either as a lack of supporting policies or as existing policies that prevent farmers from making certain management decisions on their own.

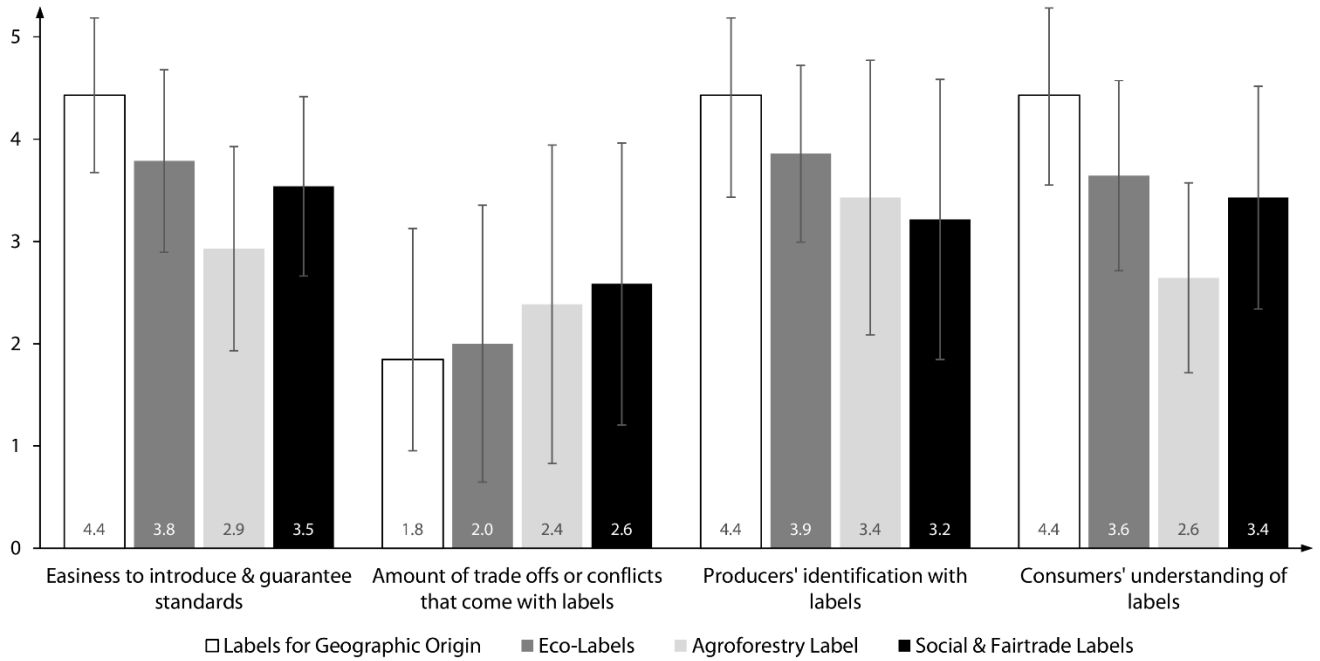

Figure 2.2 Assessment of four labeling option according to four questions. The original questions have been: i) How easy are they to introduce and to guarantee standards along the value chain?, ii) How many trade-offs or stakeholder conflicts you would expect?, iii) How well producers could identify with them?, and iv) How well can consumers understand the meaning of these labels?

As a closing question for round two, we asked for the relevance of connected concepts regarding the management or assessments of AFS. We found all four concepts rated as relevant, with multifunctionality being the most important (4.67 out of 5 Likert points) and resilience (4.44) as well as ecosystem services and social-ecological systems (both 4.33) following closely.

In round 3 we asked the respondents how they would bridge the gap for indicators, where the practical applicability was rated high, but the consumers' understanding was low or vice versa. The answers showed a slightly higher importance for educating consumers (n=12) than for training producers (n=9). The respondents consensually suggested promotion campaigns for the first and better producer education for the second issue. To avoid (n=7) or improve (n=8) problematic indicators were also selected by more than half of the respondents but received fewer comments on how to tackle the issue. At the end of round three, we asked them to assess three potential issues of agroforestry labeling and the positive potential they see regarding future labeling efforts in agroforestry production systems. They stated a high potential for future labeling efforts (3.71 Likert points out of 5) but also claimed strong concerns with regard to competing labels (3.57 points). Greenwashing (2.21 points) and market saturation for labeled products (at 2.00 points) were not assessed as potentially relevant issues.

2.4 Discussion

Relating agroforestry to sustainability

The responding experts rated 12 sustainability aspects to be relevant for capturing sustainability in AFS with the highest scores pointing to aspects of sustainable resource consumption (SDG 12), climate (SDG 13), economic growth (SDG 8), social safety (SDG 1), well-being (SDG 3) and biodiversity (SDG 15). Still, during the first step of our survey, five SDGs dropped out due to low rankings: Respondents did not see direct links of AFS with SDG 5 (gender equality), SDG 7 (clean energy), SDG 11 (sustainable cities) and SDG 14 (life below water). At the same, the low rating of SDG 2 (zero hunger) was surprising as most AFS are food systems. A possible explanation could be the low perceived importance of agroforestry systems for food production compared to large-scale monoculture systems, although studies show that AFS can achieve higher yields per area (Waldron et al. 2017, van Noordwijk et al. 2018). A second reason can be that the participating experts mainly focus on the European Mediterranean area where hunger and nutritional safety are considered less relevant issues than within the African context (Mbow et al. 2014). Furthermore, having labeling already in mind, it has to be acknowledged that for some aspects the sustainability of practices can only be indicated at the farm level. By contrast, other sustainability aspects, such as gender distribution, food security or sustainable cities have to be assessed (and regulated) on larger scales. In this regard, GIs perform differently as they work on a precisely defined landscape scale, at the same making them less sensitive to farm-scale issues.

We find a good overlapping when comparing our results with the SDGs that the FAO report on Mediterranean Forests (FAO and Plan Bleu 2018) suggests as relevant. Six of the SDGs that we identified as relevant have also been mentioned as important by FAO, but we especially miss SDG 9 (innovation and infrastructure) and SDG 12 (responsible production) in their list. Further, according to the experts' rating, a label using cultural heritage and traditional landscapes for marketing would represent SDG 9 (innovation) well. With our survey, we could show that agroforestry is not only theoretically connected to certain SDGs but experts confirm their relevance in terms of labeling. Given, that we had more than 50% overlap between the SDG-based aspects and the experts' free listing, our list of 12 sustainability aspects seems robust for representing the relevant SDGs.

Assessing indicator suitability

Based on the classification of the indicators (Table 3), we recommend eleven of them as generally applicable. In addition, we propose four of them as so-called "umbrella indicators" that are, according to our results, easy to apply, easy to understand, and can represent the key sustainability characteristics of sustainable agroforestry landscape management. Salaries of farmworkers can represent social-economic well-being, livelihood, and education. The avoidance of chemical fertilizers and pesticides supports not only the integrity of ecosystems and water bodies but also the sustainable use of resources. The use of cultural traditions and landscapes for marketing is useful for labels that emphasize terroir and regionality of production. Finally, areas that are set aside for conservation can be an indicator of the various ecological aspects of sustainability. Coinciding with our findings, the report of FAO and Plan Bleu (2018) mentions SDGs related to three of those four umbrella indicators as important for Mediterranean forestry, with clean water and conservation being highlighted as the most relevant ones.

By developing the indicators based on the SDGs we claim to cover a broader range of sustainability aspects compared to other agroforestry-specific studies. Detailed work on agricultural indicators mostly focuses on productive values and splitting indicators into the three pillars of sustainability (Escribano et al. 2018). Other studies such as Nair and Toth (2016) focus more on the broad concept of sustainability but at the same time stress the priority of ecological sustainability. Besides defining and refining ever more indicators, the group

of "Local Governments for Sustainability" (ICLEI) suggests limiting the number of indicators and the use of multifunctional indicators (Woodbridge 2015). We claim that some umbrella indicators can reflect sustainability in a wide sense, cover more than one SDG at the same time, act as a proxy value for several targets, and transfer sustainability goals to a landscape scale (Millard 2011). To not separate sustainability aspects by three sustainability pillars seems conceptually helpful when developing umbrella indicators. For sure, there are more indicators than we assessed in our survey, which could be used as umbrella indicators as well.

Barriers and potentials for agroforestry labeling

Besides stating a large general potential for labeling agroforestry products, the experts highlighted initial and ongoing costs for certification as well as the extra time required for certification efforts as major barriers, that keep farmers from joining labeling schemes. Regarding the consumer side, one expert stated that "consumers are not yet aware of all benefits of agroforestry, especially all ecosystem services provided, and do not know the term either" but the experts agreed that this could be improved by clear explanations (e.g., "clarity is needed everywhere, even more in this case with all this confusion of what is agroforestry"). They proposed to improve the understanding of labels, e.g., by educating consumers about the complexity and multifunctionality of AFS, by inventing agroforestry-specific indicators, or by developing a label specifically for agroforestry. The latter is a widespread idea within the agroforestry community, for example, supported by the European Agroforestry Federation and certain interest groups (Borremans 2019). Nevertheless, experts admit that the recognition of this label would be critically low. Thus, instead of developing a label specifically for agroforestry systems, experts point to the potential of existing labels, such as Geographical Indication (GI).

Four experts highlighted the potential of GIs with one of them stating: "A Geographical Agroforestry system that is built on the established framework of GIs and incorporates agroforestry practices" and three more respondents suggested the use of GIs or terroir characteristics for labeling in AFS. In our study, GIs were suggested for their unique potential to support cultural heritage and access to financing, which originated from relatively low-ranked sustainability aspects (see Table 3). Despite not being developed for sustainability, GIs guarantee traditional production standards and protect local specialties (Clark and Kerr 2017, Bérard and Marchenay 2006). They use the term 'terroir' to refer to product characteristics linked to a specific geographic area and landscape management. Especially for coffee and cocoa systems, studies have already shown that GIs can transmit values of sustainable landscape management to markets and consumers (Marie-Vivien et al. 2014) and also protect intellectual properties regarding place-based traditional processing techniques (Quiñones-Ruiz et al. 2015). More generally can be said that food systems are strongly interconnected with regional social-ecological characteristics and therefore highly relevant for the corresponding landscape (Penker and Wytrzens 2005) and its various values (Raymond et al. 2016). Not mentioned within the survey but in related literature, landscape labeling could be another starting point for developing an agroforestry label as this includes geographic characteristics as well but product-specific (Ghazoul et al. 2009, Ghazoul 2013).

The positive impacts of agroforestry practices on ecosystem services at a landscape level, as shown by Fagerholm et al. (2016), have been widely demonstrated. However, the connection between agroforestry landscapes and how GIs could be used to support the SDG agenda through labeling is not investigated in detail. For example, the economic benefits of GIs were documented by FAO (Vandecandelaere et al. 2018) but the benefits of maintaining traditional, valuable landscapes and practices stay unclear and should be part of further investigation. Therefore, the proposal of an agroforestry label based on terroir characteristics may express that in the social-cultural context of agroforestry landscapes, sustainability can be represented quite well through GIs. Within the current system of GIs, the strong focus on high-quality specialties and the need for a coherent local interest group limits the expansion of this approach to basic staple food products.

Limitations and outlook

The Delphi method is an approach that builds on experts' knowledge and is often characterized by small sample sizes and potential bias in the selection of study participants. Despite our efforts to include a large and broad suite of experts, the number of respondents was limited. We found that the more engaged respondents stayed until the end, as demonstrated by the fact that there were no experts leaving questions open during the last two rounds. Declining numbers of participants for each survey round (starting with 23, ending with 13 respondents) and connecting to participants with diverse professional backgrounds were problematic. Although we addressed people with different professional statuses working in agroforestry or within the labeling sector, almost exclusively experts from universities or with academic backgrounds joined our study. Therefore, we cannot claim comprehensive stakeholder participation for this survey; rather we carried out an explorative scoping based on experts' knowledge. Still, we agree with Escribano et al. (2018) that the Delphi method can synthesize expert knowledge to assess indicators and labeling approaches according to their relevance and practicability.

The necessary time to answer the questionnaires and the long lists of up to 17 items were key reasons for the declining participation rate of experts. At the same time, a clear structure, and the use of rankings (instead of ratings) were used to avoid misunderstanding and missing responses. Further, all numbers presented (rankings, Likert points, and arithmetic means of both) are not denoted as statistically significant results due to the small and less diverse sample. We treat the rankings, ratings, and free listing answers as part of a scoping that helps to understand the current issues and potentials for labeling agroforestry products.

2.5 Conclusion

Mediterranean landscapes host a variety of different agroforestry systems. Many of these extensively managed systems like Dehesas in Spain or Montados in Portugal are challenged by diminishing economic revenues. Labels have the potential to promote sustainable agroforestry management and thus raise market awareness but also advocate for the conservational value that these types of traditional landscape management deliver to society. Therefore, AFS needs different indicators compared to conventional agriculture. We found eleven indicators that were rated as useful to be assessed in the agroforestry context. By contrast, some sustainability characteristics, such as gender, no hunger, or sustainable energy were seen to be either inappropriate for a business-based certification scheme, too complex for consumers, or difficult to monitor. For scientific or administrative monitoring, more complex indicators can be considered. Meanwhile, for marketing reasons, we suggest the development of agroforestry-specific umbrella indicators that reflect the sustainable management of agroforestry landscapes in a more comprehensible way, regarding the socio-economic well-being and the integrity of social-ecological systems. Smartly designed indicators for income, rural livelihoods, and traditions as well as protection of natural resources can act as proxies for overall sustainability. Accordingly, further research is needed to develop indicators tailored to AFS. In order to assure sustainability on higher scales and to provide context-specific or complex monitoring data, the performance of labeling strategies has to be assessed in combination with governmental regulation and other related governance systems and it has to be clear that labeling is only one instrument amongst others.

We suggest that a future agroforestry label should at least partly include elements of distinct regional and geographical characteristics, such as terroir, traditional management practices, traditional processing, and place-based social-cultural values. The potential to make use of those geographical characteristics in relation to AFS is currently underestimated or at least not systematically used. Here, we see the need to investigate the interlinkage and joint application of existing labels of geographical origin, agroforestry, and the support for social-ecological sustainability.

References Chapter 2

Aertsens J, Nocker L de, **Gobin A** (2013) Valuing the carbon sequestration potential for European agriculture. Land Use Policy 31: 584–594. 10.1016/j.landusepol.2012.09.003

Aronson J, Pereira JS, Pausas JG (eds) (2009) Cork Oak Woodlands On the Edge. Ecology, Adaptive Management, and Restoration. Island Press. Washington, D.C.

Bérard L, Marchenay P (2006) Local products and geographical indications: taking account of local knowledge and biodiversity. Int Social Science J 58 (187): 109–116. 10.1111/j.1468-2451.2006.00592.x

Borremans L (2019) The development of agroforestry systems in Flanders. A farming systems research approach to social, institutional and economic inquiry. PhD Thesis, **University of Brussels**

Bugalho MN, Caldeira MC, Pereira JS, Aronson J, Pausas JG (2011) Mediterranean cork oak savannas require human use to sustain biodiversity and ecosystem services. Front. Ecol. Environ. 9 (5): 278–286. 10.1890/100084

Camilli F, Pisanelli A, Seddaiu G, Franca A, Bondesan V, Rosati A, Moreno GM, Pantera A, Hermansen JE, Burgess PJ (2018) How local stakeholders perceive agroforestry systems: an Italian perspective. Agroforest Syst 92 (4): 849–862. 10.1007/s10457-017-0127-0

Campos P, Oviedo JL, Álvarez A, Mesa B, Caparrós A (2019) The role of non-commercial intermediate services in the valuations of ecosystem services: Application to cork oak farms in Andalusia, Spain. Ecosyst. Serv. 39: 100996. 10.1016/j.ecoser.2019.100996

Clark LF, Kerr WA (2017) Climate change and terroir: The challenge of adapting geographical indications. J World Intellect Prop 20 (3-4): 88–102. 10.1111/jwip.12078

Costa A, Madeira M, Lima Santos J, Oliveira Â (2011) Change and dynamics in Mediterranean evergreen oak woodlands landscapes of Southwestern Iberian Peninsula. Landscape Urban Plann. 102 (3): 164–176. 10.1016/j.landurbplan.2011.04.002

Costa A, Madeira M, Lima Santos J, Plieninger T (2014) Recent dynamics of evergreen oak wood-pastures in south-western Iberia. In: Hartel T, Plieninger T (eds) European Wood-pastures in Transition. A Social-ecological Approach. Taylor and Francis, Hoboken, pp 70–89

den Herder M, Moreno G, Mosquera-Losada RM, Palma JH, Sidiropoulou A, Santiago Freijanes JJ, Crous-Duran J, Paulo JA, Tomé M, Pantera A, Papanastasis VP, Mantzanas K, Pachana P, Papadopoulos A, Plieninger T, Burgess PJ (2017) Current extent and stratification of agroforestry in the European Union. Agric. Ecosyst. Environ. 241: 121–132. 10.1016/j.agee.2017.03.005

Dias FS, Bugalho MN, Rodríguez-González PM, Albuquerque A, Cerdeira JO (2015) Effects of forest certification on the ecological condition of Mediterranean streams. J. Appl. Ecol. 52 (1): 190–198. 10.1111/1365-2664.12358

Egea P, Pérez y Pérez L (2016) Sustainability and multifunctionality of protected designations of origin of olive oil in Spain. Land Use Policy 58: 264–275. 10.1016/j.landusepol.2016.07.017

Elevitch C, Mazaroli D, Ragone D (2018) Agroforestry standards for regenerative agriculture. Sustainability 10 (9): 3337. 10.3390/su10093337

Escribano M, Díaz-Caro C, Mesias FJ (2018) A participative approach to develop sustainability indicators for dehesa agroforestry farms. The Science of the total environment 640-641: 89–97. 10.1016/j.scitotenv.2018.05.297

Fagerholm N, Torralba M, Burgess PJ, Plieninger T (2016) A systematic map of ecosystem services assessments around European agroforestry. Ecol. Indic. 62: 47–65. 10.1016/j.ecolind.2015.11.016

FAO and Plan Bleu (2018) State of Mediterranean Forests 2018. Marseille

Ghazoul J (2013) Landscape Labeling: Combining certification with ecosystem service conservation at landscape scales. In: Koellner T (ed) Ecosystem Services and Global Trade of Natural Resources. Routledge, pp 242–261. 10.4324/9780203816639

Ghazoul J, Garcia C, Kushalappa CG (2009) Landscape labeling: A concept for next-generation payment for ecosystem service schemes. For. Ecol. Manage. 258 (9): 1889–1895. 10.1016/j.foreco.2009.01.038

Hartel T, Plieninger T (eds) (2014) European Wood-pastures in Transition. A Social-ecological Approach. Taylor and Francis. Hoboken

Hasson F, Keeney S, McKenna H (2000) Research guidelines for the Delphi survey technique. Journal of Advanced Nursing 32 (4): 1008–1015

Hertel TW (2015) The challenges of sustainably feeding a growing planet. Food Sec. 7 (2): 185–198. 10.1007/s12571-015-0440-2

Herzog F (1998) Streuobst: a traditional agroforestry system as a model for agroforestry development in temperate Europe. Agroforest Syst 42 (1): 61–80. 10.1023/A:1006152127824

Horrillo A, Escribano M, Mesias FJ, Elghannam A, Gaspar P (2016) Is there a future for organic production in high ecological value ecosystems? Agric. Syst. 143: 114–125. 10.1016/j.agsy.2015.12.015

Huntsinger L, Oviedo JL (2014) Ecosystem services are social-ecological services in a traditional pastoral system: the case of California's Mediterranean rangelands. Ecol. Soc. 19 (1). 10.5751/ES-06143-190108

Jose S (2009) Agroforestry for ecosystem services and environmental benefits: an overview. Agroforest Syst 76 (1): 1–10. 10.1007/s10457-009-9229-7

Kanter DR, Musumba M, Wood SL, Palm C, Antle J, Balvanera P, Dale VH, Havlik P, Kline KL, Scholes RJ, Thornton P, Tittonell P, Andelman S (2018) Evaluating agricultural trade-offs in the age of sustainable development. Agric. Syst. 163: 73–88. 10.1016/j.agsy.2016.09.010

Lin BB (2011) Resilience in agriculture through crop diversification: adaptive management for environmental change. BioScience 61 (3): 183–193. 10.1525/bio.2011.61.3.4

Lorenz K, Lal R (2014) Soil organic carbon sequestration in agroforestry systems. A review. Agron. Sustainable Dev. 34 (2): 443–454. 10.1007/s13593-014-0212-y

Malek Ž, Verburg P (2017) Mediterranean land systems: Representing diversity and intensity of complex land systems in a dynamic region. Landscape Urban Plann. 165: 102–116. 10.1016/j.landurbplan.2017.05.012

Malek Ž, Verburg PH, R Geijzendorffer I, Bondeau A, Cramer W (2018) Global change effects on land management in the Mediterranean region. Global Environ. Change 50: 238–254. 10.1016/j.gloenvcha.2018.04.007

Mann C, García-Martín M, Raymond CM, Shaw BJ, Plieninger T (2018) The potential for integrated landscape management to fulfil Europe's commitments to the Sustainable Development Goals. Landscape Urban Plann. 177: 75–82. 10.1016/j.landurbplan.2018.04.017

Mann C, Plieninger T (2017) The potential of landscape labeling approaches for integrated landscape management in Europe. Landscape Res. 42 (8): 904–920. 10.1080/01426397.2017.1335863

Marie-Vivien D, Garcia CA, Kushalappa CG, Vaast P (2014) Trademarks, Geographical Indications and Environmental Labeling to Promote Biodiversity: The Case of Agroforestry Coffee in India. Development Policy Review 32 (32): 379–398

Masiero M, Amariei L, Secco L, Leonardi A, Marchetti M (2011) FSC-certified non timber forest products and forest services: is there an evidence of marketing advantages? Viterbo

Mbow C, van Noordwijk M, Prabhu R, Simons T (2014) Knowledge gaps and research needs concerning agroforestry's contribution to Sustainable Development Goals in Africa. Current Opinion in Environmental Sustainability 6: 162–170. 10.1016/j.cosust.2013.11.030

Millard E (2011) Incorporating agroforestry approaches into commodity value chains. Environmental management 48 (2): 365–377. 10.1007/s00267-011-9685-5

Montagnini F (2017) Integrating Landscapes: Agroforestry for Biodiversity Conservation and Food Sovereignty. Advances in Agroforestry, vol 12. Springer International Publishing. Cham. 10.1007/978-3-319-69371-2

Moreno G, Aviron S, Berg S, Crous-Duran J, Franca A, Jalón SG de, **Hartel T, Mirck J, Pantera A, Palma JHN, Paulo JA, Re GA, Sanna F, Thenail C, Varga A, Viaud V, Burgess PJ** (2018) Agroforestry systems of high nature and cultural value in Europe: provision of commercial goods and other ecosystem services. Agroforest Syst 92 (4): 877–891. 10.1007/s10457-017-0126-1

Mosquera-Losada MR, Santiago-Freijanes JJ, Rois-Díaz M, Moreno G, den Herder M, Aldrey-Vázquez JA, Ferreiro-Domínguez N, Pantera A, Pisanelli A, Rigueiro-Rodríguez A (2018) Agroforestry in Europe: A land management policy tool to combat climate change. Land Use Policy 78: 603–613. 10.1016/j.landusepol.2018.06.052

Mukherjee N, Hugé J, Sutherland WJ, McNeill J, van Opstal M, Dahdouh-Guebas F, Koedam N (2015) The Delphi technique in ecology and biological conservation: applications and guidelines. Methods Ecol. Evol. 6 (9): 1097–1109. 10.1111/2041-210X.12387

Mukherjee N, Zabala A, Huge J, Nyumba TO, Adem Esmail B, Sutherland WJ (2018) Comparison of techniques for eliciting views and judgements in decision-making. Methods Ecol. Evol. 9 (1): 54–63. 10.1111/2041-210X.12940

Nair PKR, Toth GG (2016) Measuring Agricultural Sustainability in Agroforestry Systems. In: Lal R, Kraybill D, Hansen DO, Singh BR, Mosogoya T, Eik LO (eds) Climate Change and Multi-Dimensional Sustainability in African Agriculture, vol 18. Springer International Publishing, Cham, pp 365–394. 10.1007/978-3-319-41238-2_20

OECD (2016) Environmental labeling and information schemes. Policy Perspectives. Paris

Pe'er G, Lakner S, Müller R, Passoni G, Bontzorlos V, Clough D, Moreira F, Azam C, Berger J, Bezak P, Bonn A, Hansjürgens B, Hartmann L, Kleemann J, Lomba A, Sahrbacher A, Schindler S, Schleyer C, Schmidt J, Schüler S, Sirami C, Meyer-Höfer M von, **Zinngrebe Y** (2017) Is the CAP fit for purpose? An evidence-based fitness check assessment. Leipzig

Pe'er G, Zinngrebe Y, Moreira F, Sirami C, Schindler S, Müller R, Bontzorlos V, Clough D, Bezák P, Bonn A, Hansjürgens B, Lomba A, Möckel S, Passoni G, Schleyer C, Schmidt J, Lakner S (2019) A greener path for the EU Common Agricultural Policy. Science (New York, N.Y.) 365 (6452): 449–451. 10.1126/science.aax3146

Penker M, Wytrzens HK (2005) Scenarios for the Austrian food chain in 2020 and its landscape impacts. Landscape Urban Plann. 71 (2-4): 175–189. 10.1016/j.landurbplan.2004.03.002

Pisanelli A, Marandola D, Marongiu S, Paris P, Rosati A, Romano R (2014) The role of Rural Development Policy in supporting agroforestry. In: Palmac JHN (ed) 2nd European Agroforestry Conference. Book of Abstracts. Integrating Science and Policy to Promote Agroforestry in Practice, Cottbus, pp 22–25

Plieninger T, Huntsinger L (2018) Complex Rangeland Systems: Integrated Social-Ecological Approaches to Silvopastoralism. Rangeland Ecol. Manage. 71 (5): 519–525. 10.1016/j.rama.2018.05.002

Pollastrini M, Chiavetta U, Cutini A, Casula A, Maltoni S, Dettori S, Corona P (2018) Indicators for the assessment and certification of cork oak management sustainability in Italy. iForest - Biogeosc. For. 11 (5): 668–674. 10.3832/ifor2587-011

Quiñones-Ruiz XF, Penker M, Vogl CR, Samper-Gartner LF (2015) Can origin labels re-shape relationships along international supply chains? – The case of Café de Colombia. International Journal of the Commons 9 (1): 416–439

Raymond CM, Bieling C, Fagerholm N, Martin-Lopez B, Plieninger T (2016) The farmer as a landscape steward: Comparing local understandings of landscape stewardship, landscape values, and land management actions. Ambio 45 (2): 173–184. 10.1007/s13280-015-0694-0

Santiago-Freijanes JJ, Mosquera-Losada MR, Rois-Díaz M, Ferreiro-Domínguez N, Pantera A, Aldrey JA, Rigueiro-Rodríguez A (2018a) Global and European policies to foster agricultural sustainability: agroforestry. Agroforest Syst 31 (1): 584. 10.1007/s10457-018-0215-9

Santiago-Freijanes JJ, Pisanelli A, Rois-Díaz M, Aldrey-Vázquez JA, Rigueiro-Rodríguez A, Pantera A, Vityi A, Lojka B, Ferreiro-Domínguez N, Mosquera-Losada MR (2018b) Agroforestry development in Europe: Policy issues. Land Use Policy 76: 144–156. 10.1016/j.landusepol.2018.03.014

Torralba M, Fagerholm N, Burgess PJ, Moreno G, Plieninger T (2016) Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agric. Ecosyst. Environ. 230: 150–161. 10.1016/j.agee.2016.06.002

Torralba M, Fagerholm N, Hartel T, Moreno G, Plieninger T (2018a) A social-ecological analysis of ecosystem services supply and trade-offs in European wood-pastures. Science advances 4 (5): eaar2176. 10.1126/sciadv.aar2176

Torralba M, Oteros-Rozas E, Moreno G, Plieninger T (2018b) Exploring the Role of Management in the Coproduction of Ecosystem Services from Spanish Wooded Rangelands. Rangeland Ecol. Manage. 71 (5): 549–559. 10.1016/j.rama.2017.09.001

Tscharntke T, Milder JC, Schroth G, Clough Y, DeClerck F, Waldron A, Rice R, Ghazoul J (2015) Conserving biodiversity through certification of tropical agroforestry crops at local and landscape scales. Conserv. Lett. 8 (1): 14–23. 10.1111/conl.12110

van Noordwijk M, Duguma LA, Dewi S, Leimona B, Catacutan DC, Lusiana B, Öborn I, Hairiah K, Minang PA (2018) SDG synergy between agriculture and forestry in the food, energy, water and income nexus: reinventing agroforestry? Current Opinion in Environmental Sustainability 34: 33–42. 10.1016/j.cosust.2018.09.003

van Oudenhoven AP, Schröter M, Drakou EG, Geijzendorffer IR, Jacobs S, van Bodegom PM, Chazee L, Czúcz B, Grunewald K, Lillebø AI, Mononen L, Nogueira AJ, Pacheco-Romero M, Perennou C, Remme RP, Rova S, Syrbe R-U, Tratalos JA, Vallejos M, Albert C (2018) Key criteria for developing ecosystem service indicators to inform decision making. Ecol. Indic. 95: 417–426. 10.1016/j.ecolind.2018.06.020

Vandecandelaere E, Teyssier C, Barjolle D, Jeanneaux P, Fournier S, Beucherie O (2018) Strengthening sustainable food systems through geographical indications. An analysis of economic impacts. Rome

Waldron A, Garrity D, Malhi Y, Girardin C, Miller DC, Seddon N (2017) Agroforestry can enhance food security while meeting other sustainable development goals. Trop. Conserv. Sci. 10: 1-6. 10.1177/1940082917720667

Woodbridge M (2015) Measuring, Monitoring and Evaluating the SDGs. Bonn

Chapter 3
EU-wide mapping of 'Protected Designations of Origin' regions

3.1 Correlation between PDO-labeled food products and social-ecological indicators
Original title: EU-wide mapping of 'Protected Designations of Origin' food products (PDOs) reveals correlations with social-ecological landscape values. *by Flinzberger L, Zinngrebe Y, Bugalho MN, and Plieninger T (2022) published in Agronomy for Sustainable Development No. 42. DOI: 10.1007/s13593-022-00778-4*

Abstract

The Geographical Indications (GIs) scheme is the EU's primary policy tool for increasing the market values of geographically distinct food products. Although GIs are linked to the landscapes of food production, little is known about the social-ecological values they represent, mainly due to a lack of spatial data. In this study, we, therefore, mapped all 638 food products labeled as Protected Designations of Origin (PDOs), using NUTS-3 areas as proxies for their actual extent, and correlated their distribution with 13 social-ecological indicators. By compiling this novel dataset, we show that the presence of PDOs strongly overlaps with environmental and cultural values. We reveal positive correlations of PDO frequency with high nature value farmland, semi-natural agriculture, tourism, and cultural heritage indicators. Further, we find that PDOs occur more often in economically weaker areas with older and declining populations. Besides differences in PDO distribution between northern and southern EU countries, we find different correlation patterns across the four largest food categories. For example, cheese and meat products are less correlated to environmental values compared to oils and fats, or fruit, vegetables and cereals. On that basis, we identify the potential of PDOs to support structurally deprived areas and propose PDOs as entry points for sustainable transformation and rural development policies – while simultaneously contributing to the conservation of cultural landscapes and their associated environmental values. As outlined in the Green Deal of the European Union and its Farm to Fork strategy, PDOs should be a part of this transformation. Based on the results of this study, we discuss more specifically for which production systems and under what enabling conditions PDOs are fit for this challenge. We recommend that future governance interventions for a sustainable transformation of EU's agriculture should take the differences across regions and product categories into account.

3.1 Introduction

Although particular agricultural systems in the European Union (e.g., high nature value farming, or agroforestry systems, as illustrated in Fig. 1 and Fig. 2) can simultaneously accomplish socio-economic and environmental targets, that is still not the case for most of Europe's agriculture (Bouwma et al. 2019; Strohbach et al. 2015). Often, economic targets and market policies are not well-balanced with the goals of environmental sustainability and human well-being (Pe'er et al. 2020). Farming trends in Europe are characterized by intensification and land abandonment processes, resulting in a loss of social-ecological landscape values (Levers et al. 2018; Quintas-Soriano et al. 2022; van Vliet et al. 2015). The European Commission has announced a Green Deal (European Commission 2019a) and a Farm to Fork strategy (European Commission 2021b) for making food systems more sustainable while linking the health of people and nature (Schebesta and Candel 2020). To incentivize this envisioned transformation of food systems, the EU strives to reform the Common Agricultural Policy, however with limited outcomes so far (Navarro and López-Bao 2019; Pe'er et al. 2019). At the same time, private market initiatives labeling food quality and origin are increasingly developed to indicate sustainability considerations and landscape values along the

value chain to final consumers (Lusk and Briggeman 2009; van Ittersum et al. 2007). The Geographical Indications (GIs) scheme was initiated in 1992 to support the incomes of rural communities by certifying the geographic origins of food products (European Council 1992). To date, there is little understanding of the interactions between labeled foods and their landscapes of origin and to what extent Geographical Indications support sustainable landscape management (Ghazoul 2013).

Figure 3.1 Open oak landscapes for grazing constitute a large share of the Iberian agroforestry system, also called Dehesa in Spain and Montados in Portugal.

Besides protecting product names as intellectual properties, the scheme also guarantees particular product traits, and traditional processing (Kizos et al. 2017). In 2017, the total volume of sales of GI products reached 7% of the European foods and drinks sector, extra-EU sales reached 15% of the EU's foods and drinks exports, and GI products achieved twice the price of comparable products (European Commission 2020). In previous research, labeling experts have praised the GI scheme as the best option for representing the sustainability of landscape-based products (Flinzberger et al. 2020), and building on that, this paper sets out to investigate this potential in depth.

Food traditions, quality, taste, and regionality are well-defined key characteristics of any Protected Designation of Origin (PDO), which is the strongest of the existing GI labels (Fournier and Michel 2017). To comply with the requirements of the GI regulation, the entire PDO production, processing, and packaging have to take place within a geographically designated area, and a producer group must specify the geographical connection of the product (Higgins 2018). The corresponding EU regulation No. 1151/2012 states "[…] 'designation of origin' is a name which identifies a product: (a) originating in a specific place, region or, in exceptional cases, a country; (b) whose quality or characteristics are essentially or exclusively due to a particular geographical environment with its inherent natural and human factors; and (c) the production steps of which all take place in the defined geographical area" (European Council 2012). For the second strictest GI label – the Protected Geographical Indication (PGI) – the same regulation defines that the product characteristics only have to be "essentially attributable to its geographical origin" (not exclusively as for PDOs), and that only "one of the production steps" needs to take place within the defined

area (European Council 2012). This study focuses exclusively on PDO products because PGIs do not always represent the necessary degree of geographic connectedness (Lamarque and Lambin 2015), compared to the PDOs' determining "inherent natural and human factors" (European Council 2012). Previous studies

Figure 3.2 Open grazing systems in Extremadura based on oak landscapes are home to the famous 'Jamon Iberico' pig meat products.

have shown how labeling can support the management of cultural and traditional landscapes and sustainable food systems (Escribano et al. 2020; Vandecandelaere et al. 2018), but also that including landscape aspects in product labels is not always easy to achieve (Dias et al. 2015; Mann and Plieninger 2017). PDOs further support rural development (Bérard and Marchenay 2006) and give economic value to cultural aspects of agricultural landscapes (Belletti and Marescotti 2011). At the same time, the intensification of successful GIs bears the risk of compromising environmental benefits (Belletti et al. 2015; Vakoufaris et al. 2014). Thus, it needs differentiated and specified management practices when employing PDOs as instruments for supporting sustainable food systems.

To date, there is no EU-wide overview of the geographical distribution and extent of PDOs. This is hampering the possibilities of spatial analyses to better understand GIs and their product-landscape relationships. Some countries have started national geo-data platforms providing the spatial data of registered PDO areas, but the data is neither available for all EU countries nor is it accessible in a uniform format. Our study aims to close this gap by presenting the first map of the regional distribution of all 638 PDO-labeled food products within the EU28 and showing how this distribution pattern correlates with various social-ecological indicators (in this article, we are referring to 'EU27+UK' as 'EU28'). Thereby, we demonstrate the analytical potential of this type of dataset by revealing linkages between high-quality food products and the maintenance of valuable agricultural landscapes. We thus explore why PDOs are an interesting policy option for supporting the sustainable management of culturally imprinted food landscapes.

3.2 Materials and methods

Data acquisition

By the end of 2020, 1823 products were registered as Protected Designations of Origin (PDOs) on the European Commission's eAmbrosia database (European Commission 2021a). Although the registration of a PDO requires a group or consortium to define a bounded area in which the product can be produced, the relevant geographical areas have so far been described by plain-text files only. The spatial data partially provided by some national agencies have no uniform structure and are for many countries not available at all. Thus, to carry out a spatial analysis using the distribution of PDOs, we mapped those geographical areas by retrieving the spatial extent from the official text documents describing all product characteristics, including the geographical area. Further, we excluded 1175 wine products. This was done for two reasons: First, we had to reduce the number of products to a reasonable amount to carry out the mapping, handle the data, and avoid oversampling wine products as well. Secondly, to align our research with the EU's Farm to Fork strategy, we focused exclusively on food products – reflecting that this strategy also does not mention wines or other alcoholic drinks. Therefore, we carried out the mapping for 638 PDO-labeled food products that had been registered by 30 June 2020 within the EU28.

Geographical mapping of PDOs

For the mapping of the registered PDOs, we used the European NUTS-3 regions as spatial reference units (the lowest level of the EU's standardized 'Nomenclature of Territorial Units for Statistics'). This territorial unit appeared most useful as many geographical areas of the registered products were defined at local scales close to or equal to NUTS-3. In cases where the spatial extent of PDOs was defined on a finer scale (or limited to certain altitudes), we still mapped the entire applicable NUTS-3 region as a corresponding production area. Also, the statistics from the European Statistical Office (EUROSTAT) or the European Environmental Agency (EEA) were commonly available at the local scale (NUTS-3) or the regional scale (NUTS-2). For these reasons, mapping the PDOs at the NUTS-3 level was a compromise for practicality and data availability. Considering the scale of the EUROSTAT and EEA statistics, all of the correlations between PDOs and social-ecological indicators were calculated at the NUTS-3 level. Some of the older legal documents from the beginning of the GI scheme (1996-1997) were only available as scanned typewritten documents, or in their original language (e.g., only in Greek). In rare cases, legal documents were completely missing, and we had to define the geographical area using information from third-party websites. Three bi-nationally registered products (from Slovenia/Croatia and Poland/Lithuania) were treated as separate products in each of the two countries. Three products from non-EU territories of the UK (Jersey and the Isle of Man) were excluded from the analysis, as there were no official statistics available on EUROSTAT for those islands. After mapping each PDO product separately, we merged all the shapefiles for each country and the EU28 countries combined. Subsequently, by dissolving the total dataset by its 1348 NUTS-3 regions, we expressed the number of PDO products that can be produced in every single region – in a 'PDO score'.

Selecting the social-ecological and structural indicators

To investigate the correlation of the PDO scores with the social-ecological landscape values, we selected 13 indicators (Table 1). The basic criteria for selecting the indicators were complete data availability at either the local or regional level and reasonable representativeness for the indicator category (e.g., the number of UNESCO World Heritage sites and the number of tourism beds were used to represent the cultural value of a given region). As presented in Table 1, we acquired eight of the 13 indicators directly from the EUROSTAT database and two from the EEA database. Institutionally serviced databases like that from EUROSTAT or EEA provided the benefit of uniform data (e.g., regarding the territorial units), and the

availability of data as complete as possible. Two more indicators were built from a raster dataset from the 'Copernicus Land Monitoring Service' using Corine landcover data, and the indicator for UN World Heritage sites was constructed from point data acquired from the UNESCO website. All these indicators have previously been used in similar fields of research as useful proxy values for social-ecological assessments (Bennett et al. 2018; Malek et al. 2018; Raymond et al. 2016). We selected environmental indicators based on their relationship with landscape values. High nature value farmland (HNVF), which features many forms of small-scale, less-intensive, and traditional agricultural lands (Lomba et al. 2019), was selected as a key indicator because of its holistic connection to social-ecological landscape values (Kizos et al. 2012; Plieninger et al. 2019).

Table 3.1 Type and origin of social-ecological indicators. The data used for this study were mostly acquired from the official European statistical databases of EUROSTAT and EEA. Below we present the units, data range, sources, and year of each dataset. Indicators marked with asterisks were acquired at the NUTS-2 level. a) Corine (Coordination of Information on the Environment) is an EU landcover classification system. b) UAA stands for utilized agriculture area. c) GDP stands for gross domestic product.

Indicator	Range	Unit	Source	Year
Ecological and cultural indicators				
High nature value farmland	0 - 81.0	*% of total area*	EEA: eea.europa.eu/.../high-nature-value-farmland	2012
Natura 2000	0 - 75.0	*% of total area*	EEA: eea.europa.eu/data-and-maps/data/natura-11	2019
Corine[a] landcover richness	0 - 41.0	*no. of classes*	COPERNICUS: land.copernicus.eu/.../corine	2018
Semi-natural farmland	0 - 53.9	*% of total area*	COPERNICUS: land.copernicus.eu/.../corine	2018
Tourism beds	0 - 367,400	*no. of beds*	EUROSTAT: eurostat.ec.europa.eu/...tour_cap	2011
UNESCO World Heritage sites	0 - 9	*no. of sites*	UNESCO/WHC: whc.unesco.org/en/syndication	2013
Organic farming*	0 - 54.3	*% of UAA*[b]	EUROSTAT: .eurostat.ec.europa.eu/...organic	2013
Socio-economic indicators				
Population density	2 - 21,000	*pop. per km²*	EUROSTAT: eurostat.ec.europa.eu/...demo_r_d	2018
Median age	18.1 - 55.5	*years*	EUROSTAT: eurostat.ec.europa.eu/...demo_r_pjan	2019
5-year population change	-14.5 - 17.0	*% of population*	EUROSTAT: eurostat.ec.europa.eu/...demo_r_pjangrp	2018
GDP[c] per capita	3,100 - 501,600	*Euros*	EUROSTAT: eurostat.ec.europa.eu/...nama_10r_3gdp	2016
Unemployment rate*	0 - 30.1	*% of population*	EUROSTAT: eurostat.ec.europa.eu/...fst_r_lfu	2019
Average farm size*	0 - 274	*ha UAA*	EUROSTAT: eurostat.ec.europa.eu/...aareg	2016

The proportion of Natura 2000 areas, a pan-European network of protected areas, was selected because sustainable farming in these protected areas has environmental benefits (Underwood 2014). For HNVF and Natura 2000, a visual similarity of distribution patterns with the PDO score is apparent and, for illustrative reasons, is presented in Fig. 3. The richness of landcover and the percentage of semi-natural agricultural farmland (including agroforestry) were included as additional indicators of environmental value. Landcover richness was calculated from the number of Corine landcover classes present in a given region, and semi-natural agriculture was calculated as the percentage of the land covered by one of three Corine landcover classes: agroforestry, agricultural land with nature areas, and complex agricultural patterns. Further, the number of tourism beds and UNESCO World Heritage sites represented multi-dimensional aspects of cultural values (Parga-Dans et al. 2020). Standard agricultural and socio-economic datasets from EUROSTAT were used as indicators of prevailing farm structure and socio-economic development of a given region.

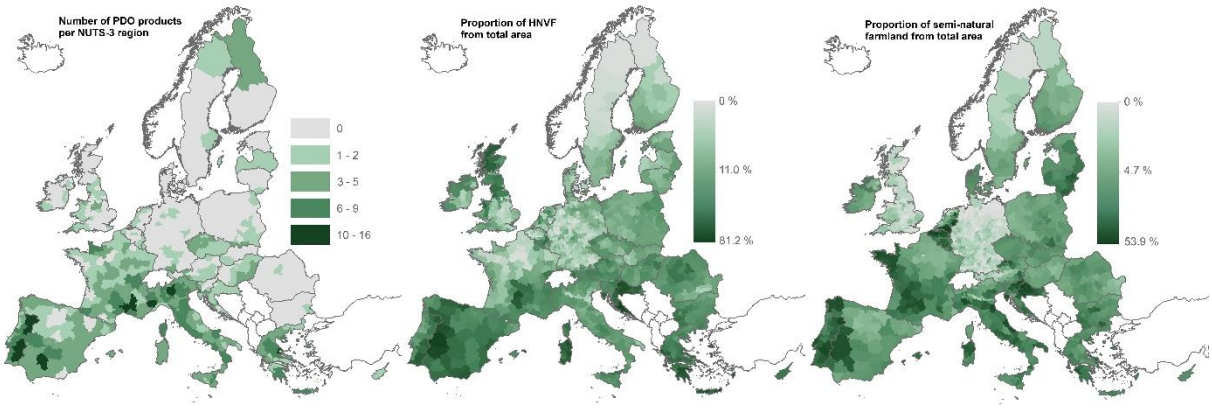

Figure 3.3 Distribution patterns among 'Protected Designation of Origin' (PDO) score and two significant indicators. The visually perceivable similarity of the spatial distribution of PDO scores (left), high nature value farmland (HNVF) (center), and semi-natural farmland (right) already indicated a correlation. NUTS-3 is the abbreviation for the lowest scale of the European Unions 'Nomenclature of territorial units for statistics'.

Descriptive statistical analysis

The number of PDO products attached to each region – the PDO score – formed the value against which we tested correlations for the 13 social-ecological indicators. Our main analysis method was a separate spatial correlation of the PDO score and each of the 13 selected indicators. Thereby, all 1348 NUTS-3 regions were included in all calculations, even those in which no PDOs occurred. All correlations were calculated at the NUTS-3 level (as explained in section 2.2). Indicator data acquired at the NUTS-2 level was downscaled to NUTS-3, assuming the same values for the subordinate regions. In addition to the overall correlations, we calculated the specific regional and product category correlations for all 13 indicators. Regionally, we split the dataset into the Mediterranean countries (IT, FR, ES, GR, PT, HR, SI, CY), and the rest of the EU28 (not considering Malta for the Mediterranean, as it had no registered PDO). Further, we distinguished the four most frequent product categories, namely meat (categories 1.1 and 1.2), cheeses (1.3), oils and fats (1.5), and fruit, vegetables and cereals (1.6). Fresh meat (1.1) and processed meat (1.2) were treated as a combined category throughout the entire study, and the category 'other products of animal origin' was not considered at all, as it included products of disparate characteristics (e.g., eggs, honey, and dairy products). For the total PDO dataset and all the above-mentioned product categories, we calculated the PDO score separately. By using the numerical values of the PDO score, we created heatmaps showing hotspots and clusters of PDO production in the European Union (Fig. 4), and we also differentiated the heatmaps by product categories (Fig. 5).

The correlation values in the smaller sub-samples (e.g., non-Mediterranean countries, which had only 96 of the 638 PDOs) can differ due to unknown causalities, or the correlation can be small or non-significant because of the small sample. However, the overall trends showed no signs of statistical-methodological artifacts that cannot be explained in this way. For example, organic farming did not correlate significantly with any of the product categories. Also, the correlations with most of the agricultural and demographic indicators were small or non-significant for the rest of EU28 but were consistent for the Mediterranean countries. Finally, to relate the correlations of different product categories to the average size of the legally registered area, we calculated the area sizes for all PDOs and averaged them for all sub-categories using arithmetic means. Although the sizes of the PDO areas can be influenced by the different sizes of NUTS-3 areas, generally the NUTS regions are meant to divide the territory into units with similar population numbers.

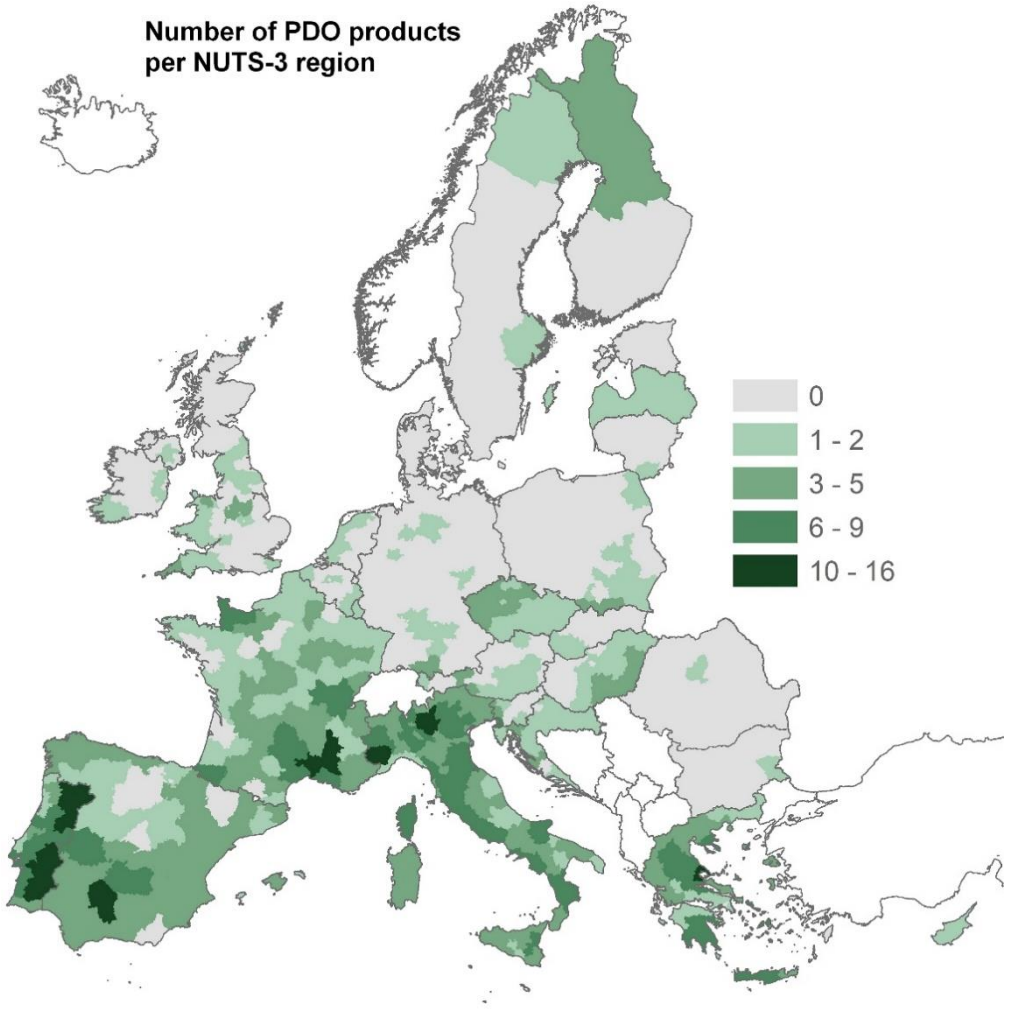

Figure 3.4 Protected Designation of Origin' (PDO) distribution in the former European Union 28 member states. The map presents the number of PDOs that can be produced in each NUTS-3 region (indicated by lighter and darker shades of green), revealing hotspots in Portugal, Spain, France, Italy, and Greece, and showing the Mediterranean dominance. NUTS-3 is the abbreviation for the lowest scale of the European Unions 'Nomenclature of territorial units for statistics'.

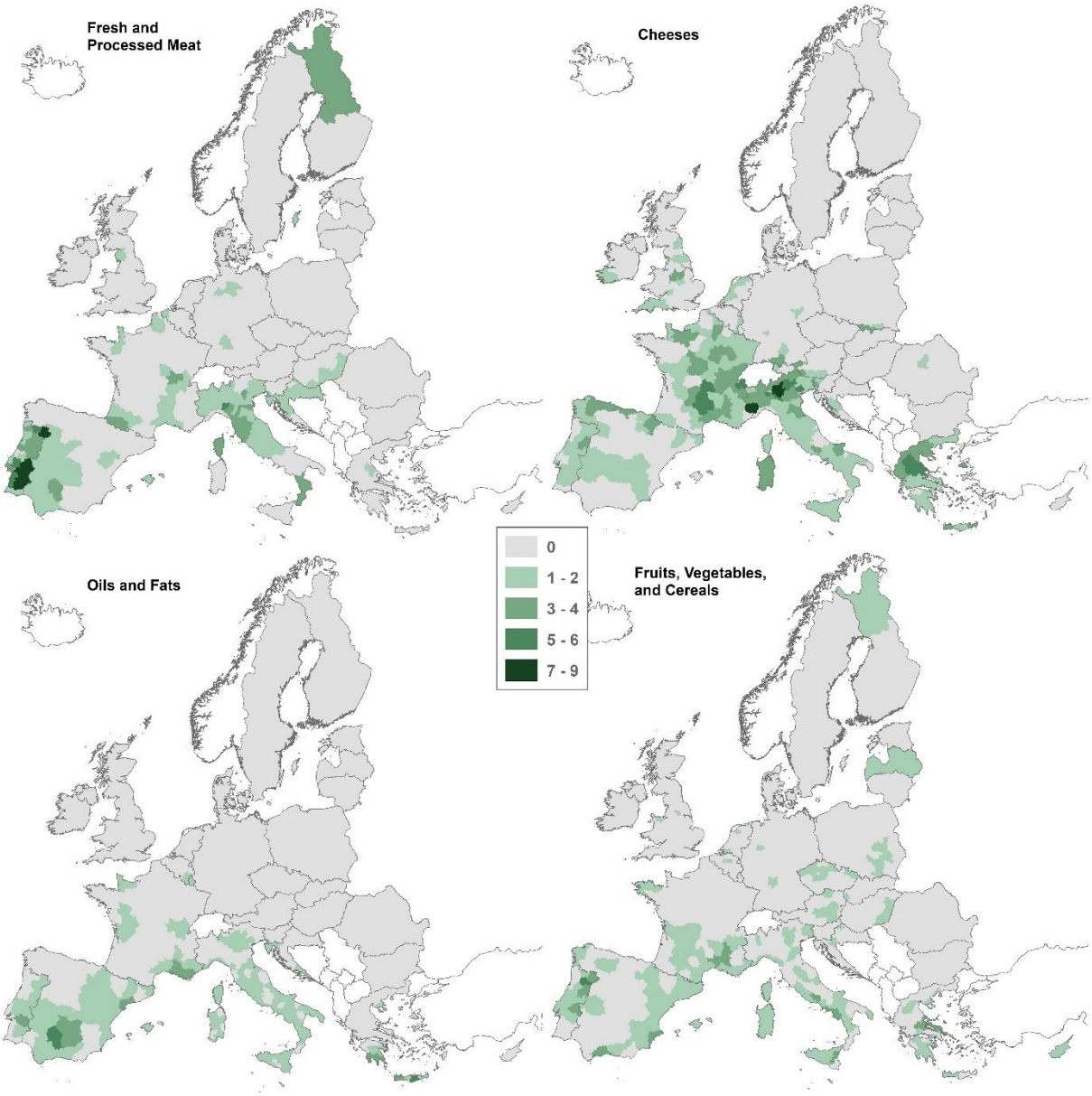

Figure 3.5 Spatial distribution of the most frequent product categories. Different types of PDO products are distributed differently across Europe. At NUTS-3 level, meat and cheese products show more pronounced hotspots and higher degrees of clustering than oils and fats, or fruits, vegetables, and cereals. Green shades indicating the number of PDOs present in each NUTS-3 region. NUTS-3 is the abbreviation for the lowest scale of the European Unions 'Nomenclature of territorial units for statistics'.

3.3 Results

Spatial distribution of PDOs

PDO-labeled foods were found to be unequally distributed across geographical areas. At a national level, 84.9% of the products (542 out of the 638) were registered in eight Mediterranean countries: Portugal, Spain, France, Italy, Slovenia, Croatia, Greece, and Cyprus. At the local level, we identified five regions with ten or more registered PDO products (hotspots of PDO production) in western Portugal, southern Spain, northern Italy, southeast France, and a small area on Greece's mainland (Fig. 4). On a regional scale, the larger areas of high PDO abundance were found in Portugal, southern Spain, southern France, northern Italy, Sicily, and Crete. The PDOs were dominated by cheeses (30.1%), fruit, vegetables and cereals (23.7%), and oils and fats (18.5%), complemented by fresh (6.6%) and processed (6.0%) meat products. We found no relevant difference between the Mediterranean and non-Mediterranean countries in their relative shares of fruit, vegetables and cereals, cheese, and meat PDOs. By contrast, oils and fats PDOs were ten times more frequent in the Mediterranean countries (21.4% vs. 2.1%). The average size of a PDO-producing area was around 13,000 km2, but the average meat PDO extended across a considerably larger territory (over 23,000 km2). While the average cheese PDO covered almost 14,000 km2, the average oils and fats PDO covered around 9300 km2, and the average fruit, vegetables and cereals PDO around 8500 km2 (Table 2).

Table 3.2 Total 'Protected Designation of Origin' (PDO) numbers and average sizes of production areas (in km²). The five most frequent product categories were selected for this study, as they dominate most of the PDO market. The total numbers of PDOs and the average sizes (arithmetic means) of legally registered production areas are differentiated by product categories and regions. The categories were copied from the EU eAmbrosia database. Fresh meat and processed meat were merged into one category.

	Overall		Mediterranean		non-Mediterranean	
PDO category	Number of PDOs	avg. size [km²]	Number of PDOs	avg. size [km²]	Number of PDOs	avg. size [km²]
Fresh and processed meat	80	23,809	67	19,889	13	43,710
Cheeses	192	13,827	160	15,382	32	6,051
Oils and fats	118	9,229	116	9,329	2	3,441
Fruits, vegetables, and cereals (fresh crops)	151	8,526	130	7,646	21	14,014
Other products of animal origin	37	10,379	31	10,995	6	7,197
Fresh fish	12	26,437	5	8,298	7	39,393
Other products (spices, etc.)	30	18,434	20	12,757	10	29,787
All other categories	18	7,013	13	6,356	5	8,724
Total	638	13,011	542	12,136	96	17,953

Correlation of PDOs and social-ecological indicators

All environmental and cultural indicators (except for organic farming) showed a clear positive correlation for most product categories (Table 3). The presence of high nature value farmland (HNVF), the share of semi-natural agricultural landcover, and the number of different Corine landcover classes (CLC richness) in a given region had the strongest correlations overall. The correlations of the PDO score (number of PDOs in each NUTS-3 region) with Natura 2000 areas, with the number of UNESCO World Heritage sites, and with the number of tourism beds were lower, but they showed the same pattern. Stronger correlations were found for the sub-samples of oils and fats, as well as fruit, vegetables and cereals (Table 3). HNVF and the number of tourism beds were correlated strongly and positively with the non-Mediterranean PDO scores, but landcover richness and semi-natural farmland were correlated more strongly with PDO scores in Mediterranean countries. Semi-natural farmlands showed the strongest correlation with the frequency of meat PDOs out of all the food categories. Remarkably, organic farming was not correlated with the presence of PDOs. All the demographic indicators showed a spatial overlap between PDO scores and rural regions

with smaller, declining, and older populations. For these three indicators, this relationship was stronger for the Mediterranean countries and weaker, or non-significant, for the non-Mediterranean countries, which had a considerably smaller sample size of PDO products. Median age and a 5-year population decline also showed their strongest correlations for meat PDO scores compared to other food categories (Table 3). In economic terms, a lower GDP per capita and a higher unemployment rate were correlated with PDOs. GDP per capita was mostly indifferent among most sub-categories, being slightly more negatively correlated for fruit, vegetables and cereals. A strikingly high correlation of unemployment rates with the overall PDO score stood in contrast to a negative correlation for the Mediterranean sub-sample. Among the product categories, the frequency of meat PDOs showed the smallest correlation with unemployment rates. Smaller average farm sizes were correlated with PDO scores but not for non-Mediterranean countries.

Table 3.3 Correlations of the 'Protected Designation of Origin' (PDO) score and 13 social-ecological indicators. Results of the paired correlations (correlation coefficient r), differentiated by product categories and regions (p-values $p < 0.05$: *). Correlations that are relevant to the discussion are printed in bold. a) Med. stands for Mediterranean. b) Corine (Coordination of Information on the Environment) is an EU landcover classification system. c) Semi-natural farmland includes three Corine landcover classes: 'agroforestry', 'agricultural land with nature areas', and 'complex agricultural patterns'. d) GDP stands for gross domestic product.

Indicator	all EU28 products	Meat	Cheese	Oils and fats	Fresh crops	Med.[a] countries	non-Med.[a] countries
Number of cases (n)	638	80	192	118	151	542	96
Ecological and cultural indicators (correlation coefficient r)							
High nature value farmland	**0.39***	0.22*	0.27*	**0.29***	0.27*	0.09	**0.20***
Natura 2000	**0.22***	0.09*	0.13*	**0.20***	0.16*	0.03	0.05
Corine[b] landcover richness	**0.48***	0.28*	0.30*	**0.36***	**0.36***	**0.33***	0.12*
Semi-natural farmland[c]	**0.39***	**0.32***	0.21*	0.24*	0.28*	**0.13***	0.05
Tourism beds	**0.22***	0.09*	0.13*	**0.22***	0.17*	0.09	**0.20***
UNESCO World Heritage sites	**0.23***	0.11*	0.13*	**0.21***	0.18*	0.13*	0.14*
Organic farming	-0.06*	-0.03	-0.05	-0.02	-0.03	-0.05	-0.02
Socio-economic indicators (correlation coefficient r)							
Population density	**-0.14***	-0.09*	-0.09*	-0.08*	-0.09*	-0.15*	-0.10*
Median age	**0.17***	**0.18***	0.15*	0.06*	0.09*	**0.30***	-0.05
5-year population change	**-0.23***	**-0.21***	-0.12*	-0.12*	-0.14*	**-0.12***	0.02
GDP[d] per capita	**-0.13***	-0.07*	-0.06*	-0.08*	-0.10*	0.01	-0.05
Unemployment rate	**0.44***	0.16*	0.37*	0.37*	**0.33***	**-0.18***	-0.01
Average farm size	**-0.20***	-0.13*	-0.14*	-0.14*	-0.15*	**-0.18***	0.05

3.4 Discussion

To gain a better understanding of how well 'Protected Designations of Origin' (PDOs) reflect multiple values of agricultural landscapes, we related the spatial extent of PDOs to different social-ecological indicators on a large spatial scale. A major barrier limiting research on 'Geographical Indications' (GIs) was the lack of precise and digitally available geographical data regarding the delimitation of PDO regions – a prerequisite for research, monitoring, and management. For a comprehensive investigation, our self-mapped subset of PDOs covered all 638 food PDOs in the EU28 (by 30 June 2020). We derived from our results that PDOs have a well-established relationship to landscape values. For the correlations, we grouped the registered PDO products into four food product categories (meat, cheese, oils and fats, and fruit, vegetables and cereals), revealing recurring patterns of landscape-product relationships. Further, by differentiating between the Mediterranean and the non-Mediterranean countries, we found a substantial difference in both the number of registered PDOs and the correlations with landscape characteristics. However, the relatively small number of non-Mediterranean PDO products led to less significant correlations (see significance markers in Table 3).

PDOs are predominantly located in the Mediterranean countries

An obvious difference between southern and northern Europe is the number of registered products, with 85% of PDOs being produced in eight Mediterranean countries. The underlying reasons for this may be found in traditions regarding landscape management and food cultures as represented by the Mediterranean diet. Further, political support for PDO registration as well as the climatic and environmental prerequisites (e.g., higher levels of biodiversity) may have played a role in some Mediterranean countries (Kizos et al. 2017; Quiñones-Ruiz et al. 2016). A consequence of these complex and not fully understood causalities is that PDOs are economically a lot more relevant in the Mediterranean food sector, while in non-Mediterranean countries, they are mostly niche products (Spiller and Tschofen 2017). This becomes particularly evident in the positive correlation between the employment rate and the number of PDOs within the Mediterranean countries. The fact that high nature value farmland (HNVF) showed a stronger relationship with PDO scores in the non-Mediterranean countries could be another result of more niche-market PDOs, which target a few extraordinary landscapes and aim mostly for domestic markets. In comparison, the production of highly successful Mediterranean PDOs – cheeses in particular – is oriented towards mass markets and global exports. Those cheese PDOs feature high volumes of annual production: For example, around 200,000 tons of Grana Padano (clal.it 2021), 120,000 tons of Feta (dairyreporter.com 2021), and 70,000 tons of Comte (agri71.fr 2021) are produced every year.

Population declines and aging populations were only correlated with the PDO scores in Mediterranean countries. At the same time, we found stronger correlations between landcover richness and semi-natural farmland in Mediterranean countries. Thus, a promising strategy for further PDO development in the Mediterranean may be to harness social-ecological synergies, by linking the improvement of rural livelihoods with the maintenance of valuable agricultural landscapes. However, for such synergies to happen, PDOs would need to support land management practices that are more clearly directed towards environmental and cultural values, such as agroforestry, low intensity, and mosaic-like land use, silvopastoral grazing systems, or HNVF practices (García-Martín et al. 2021). Like HNVF, the number of tourism beds was more strongly correlated with the PDO score in the non-Mediterranean countries, pointing towards a more selective registration of PDOs in environmentally valuable and culturally unique regions. The high number of PDOs in the Mediterranean is possibly also rooted in the high societal importance of the Mediterranean diet – acknowledged as an intangible cultural heritage by UNESCO (Bonaccio et al. 2021). Based on a high degree of biodiversity, more regional and typically traditional products evolved in the Mediterranean (Blondel 2006; Padilla et al. 2012). We assume that because of the Mediterranean diet's societal importance, regionality and product quality of food have been more important to Mediterranean consumers long since (Escribano et al. 2020). The fact that the Mediterranean diet has been proven to be healthier and more sustainable than the average northern European diet probably makes PDOs a suitable instrument for promoting sustainable and healthy food systems as well.

PDOs target environmentally and culturally valuable landscapes

The consistent correlations between the presence of PDOs and our indicators of environmental and cultural values pointed towards a strong representation of low-intensity and traditional farming systems in PDO production. Those characteristics are often linked to the concept of HNVF, especially in the Mediterranean region (Plieninger et al. 2021). The presence of PDOs showed a particularly strong congruence with HNVF areas, which are described as small-scale, extensive, traditional, and diverse systems (Lomba et al. 2019). Natura 2000 areas also overlapped with PDO production areas, probably because many of these protected areas include low-intensity livestock grazing systems on marginal and less productive lands (Underwood 2014). The richness of landcover and semi-natural farmland (two indicators based on Corine landcover data) also correlated with the presence of PDOs. The fact that a combination of agroforestry, agricultural land with natural areas, and complex agricultural patterns showed a clear positive correlation for all sub-categories

may be the consequence of PDOs coinciding with structurally and functionally diverse landscapes. Also, the occurrence of PDO hotspots on the Iberian Peninsula, in Italy, and Greece reflected this revealed relationship, as the Mediterranean Basin is recognized as an HNVF hotspot of Europe (García-Martín et al. 2021; Plieninger and Bieling 2013).

Many PDOs are an inherent part of multi-functional agricultural systems. By contrast, a stronger specialization in single, internationally traded products can reduce the environmental benefits of originally sustainable landscape management (García-Martín et al. 2021). Regarding the large extent of some PDO areas being registered – for example, the Italian 'Salamini Italiani Alla Cacciatora' covering around 50% of Italy's territory, or 'Český Kmín' covering the whole of the Czech Republic – we have slight concerns too. There should be some scrutiny if such large PDO territories make sense, given that it is impossible to establish strong linkages to distinct landscapes at such vast geographic scales. For further research, we suggest investigating under which circumstances large farm sizes can lead to less desirable environmental and socio-demographic production characteristics.

Assuming that the numbers of tourism beds and UNESCO World Heritage sites are indicators for cultural appreciation, PDO-rich regions appear to be touristically attractive. The PDO scores for fruit, vegetables and cereals, as well as for oils and fats PDOs, were correlated more strongly with cultural appreciation than cheese or meat PDOs, possibly because the respective animals are not always part of the landscapes but kept in staples. Therefore, we assume that the categories of plant-based PDOs are more closely related to culturally relevant landscape features and thus represent the emotional and aesthetic attachment to their landscapes of origin more clearly. Similarly, silvopastoral grazing systems like the Mediterranean grazed oak woodlands (Dehesas and Montados) are known for being embedded into highly aesthetic cultural landscapes (Plieninger et al. 2015; Scolozzi et al. 2012) and for being associated with conservation values (Bugalho et al. 2011). This may explain the stronger correlation between semi-natural farmlands and PDOs from the Mediterranean countries (e.g., 'Presunto do Alentejo' or similar pig meat products, widely known as 'Jamón Iberico').

The absence of a correlation between organic production and PDOs may reflect competing ideals in the organic vs. regional food debate. For instance, Denmark has the highest share of organic sales values by far, but there is not a single PDO registered in the country (European Commission 2019b).

PDOs are linked to rural areas lagging behind in socio-economic development

By design, PDO food products are targeted at rural regions and are deeply embedded into the traditional socio-economic systems of these regions (Egea and Pérez y Pérez 2016; Raimondi et al. 2018). However, our analysis showed that PDOs are not explicitly linked to successful rural development. On the contrary, PDOs occurred more often in areas for which the indicators pointed towards a rural exodus, characterized either by the abandonment of land management and social structures (van Vliet et al. 2015), or by intensification processes (Bruno et al. 2021). Unlike the results for cultural values, it appeared that the presence of PDOs was negatively correlated with the economic success of a region (as expressed by GDP). Although unemployment rates showed a relatively strong correlation with PDOs in general, it was the opposite for PDOs in the Mediterranean countries (Table 3). At the same time, smaller farm sizes were significantly correlated with a higher number of registered PDOs within the Mediterranean only (not so in non-Mediterranean countries). Field research based on case studies is necessary to fully capture the meanings of these and other correlations and to investigate how PDOs can contribute more comprehensively to rural development. We speculate that the idea of the GI scheme to support rural livelihoods (particularly in marginalized areas) does work, but there is potential for improved performance.

PDOs were even more strongly correlated with older and declining populations than with low population densities. Thus, the demographic situation of PDO-rich regions is not only geographically remote or socio-economically marginalized in a static sense but characterized by a trend towards rural exodus. In the Mediterranean region – home to most PDOs – the higher average median age of the population was even more strongly correlated with PDO presence. This trend towards rural out-migration, with a lack of labor and a cultural drain, can threaten the maintenance of traditional agricultural landscapes and related sustainable management practices, and finally, lead to the complete disappearance of the traditional systems. The high correlation of meat PDOs with older and declining populations went along with a lower correlation for unemployment. These diverging trends show that, although a population decline may pose a threat to the maintenance of PDOs in general, it may be successfully tackled with finely tuned approaches that consider the different product categories. As we have shown that PDOs occur more often in demographically deprived rural areas, we see it as a promising future task to investigate which product types could be particularly helpful for improving rural situations and livelihoods.

While PDOs mainly represent traditional products and practices, innovation and climate change adaptation are also important for maintaining their market relevance and attracting consumers. Especially concerning climate change and agriculture, the PDO-rich Mediterranean region will be one of the most affected regions in Europe (Schröter et al. 2005). Already today, certain plant species or varieties that are necessary raw materials for PDO products are threatened by climate-change-induced droughts or pests (Chacón-Vozmediano et al. 2021; Clark and Kerr 2017). However, the literature shows an imbalance in the amendments to PDOs (updates to their legal documents) targeting economic aspects way more often than environmental or cultural aspects (Quiñones-Ruiz et al. 2018).

Correlations between PDOs and social-ecological values vary between food products

Looking at the four food categories (meat, cheeses, oils and fats, and fruit, vegetables and cereals) separately, we revealed different spatial hotspots for each category (Fig. 5) and found relevant differences regarding the correlations with indicators for social-ecological values (Table 3). For example, 77% of the income from cheese GIs – the category with the highest sales volume by far – is generated in four Mediterranean countries: Italy, France, Greece, and Spain (European Commission 2020). At the same time, the production areas of cheese PDOs were, on average, almost three times larger in the Mediterranean than in non-Mediterranean countries (Table 2). While meat products were spatially concentrated in regions of western Portugal (which are dominated by open grazing woodlands), cheese PDOs were most frequent in southern France, and northern Italy (where more industrialized milk production occurs). However, we acknowledge that cheese and meat PDO products, in particular, have been historical core products of the GI scheme (European Commission 2020), and in some cases are the economic basis for landscape maintenance (Bérard and Marchenay 2006). For further research, it will be interesting to see to what extent the landscape concept behind PDOs is congruent with other usages of the landscape concept – especially for conservation purposes.

Oils and fats showed less pronounced hotspots, but they were almost exclusive to the Mediterranean landscapes with their semi-arid climate and longer vegetation periods. Finally, 'fruit, vegetables and cereals' was the most evenly spread category, with only small hotspots in Portugal, central Italy, and northern Greece. Despite similar total numbers of registered PDOs (Fig. 5), we observed less structural clustering for oils and fats, and fruit, vegetables and cereals, probably indicating more dispersed production patterns than for meat or cheese. Also, many legal documents for olive oil PDOs limit the production intensity to a certain threshold, to protect the underlying ecosystems and prevent quality trade-offs (Belletti et al. 2015). Furthermore, the difference in the average geographical area for the different PDO categories was considerable. The average PDO area for processed meat (23,800 km2) was around two and a half times larger than the average PDO area for oils and fats (9200 km2) or fruit, vegetables and cereals (8500 km2).

PDO-labeled cheese products also featured larger areas on average (13,800 km2) and especially large areas in the Mediterranean countries (15,400 km2) (Table 2). From this, we conclude two-fold: First, that animal-based PDOs need larger territories to source enough animal food supply, and second that PDOs with larger production volumes need larger territories as well. Also, some PDO clusters based on open grazing systems may have evolved in specifically suitable and unique landscapes. The natural characteristics of grazing systems such as the Dehesa and Montados of Spain and Portugal, or the Cevennes in France favor low-intensity production and hence comprise larger PDO territories for grazing animals (Berriet-Solliec et al. 2018). Overall, it appeared that PDOs for more highly processed foods, such as meat or cheese, were rooted in economically stronger regions. That makes sense given the higher added value within higher processed food products. At the same time, those further processed products also appear to develop larger clusters with more centralized processing units. Further investigation could test whether the correlations for highly intensified wine production systems – which economically make up a relevant part of the GI scheme – support these assumptions.

3.5 Conclusions and policy recommendations

The mapping of 638 PDO products at the level of the EU's NUTS-3 regions revealed novel insights into the present system of Geographical Indications (GIs). Based on our correlations of this map with social-ecological indicators, we identified three potentials for the PDO label, specifically concerning the implementation of the EU's sustainability agenda as outlined by the Green Deal and the Farm to Fork strategy.

First, we have shown that the occurrence of oils and fats in particular, as well as fruit, vegetables and cereals labeled as PDOs, is more strongly linked to environmental and cultural values, compared to meat or cheese PDOs. PDO requirements will need to address these significant differences in terms of environmental quality, socio-economic viability, and production structures to indicate more homogenous production characteristics to consumers. Landscape features, as well as environmental integrity and connectivity, are essential elements to be taken into account when implementing the Farm to Fork strategy within the GI scheme. Given the risks of an economically motivated over-intensification of PDO production on the one hand and large production areas with questionable landscape-product relationships on the other hand, we recommend a general fitness check of the PDOs. As the Farm to Fork strategy itself has been criticized for the generic nature of its goals (Schebesta and Candel 2020), a potential PDO fitness check should assess whether the original idea of local food products is preserved. It has to be ensured that PDOs are tightly linked to their landscapes of origin and that sustainable management will be possible under future circumstances regarding demography, ecology, and climate.

Secondly, our results show that PDOs provide a powerful, but not very effectively used potential to contribute to income opportunities in rural regions. While it seems that the environmental benefits of PDO production vary across different product types, the linkage with negative demographic trends seems to be the normality. Therefore, we recommend making further use of PDOs to support the development of rural areas. To do so successfully we see a great necessity to carry out qualitative case studies at a farm and landscape level, investigating PDO producers' motivations, value chains, and interests of external stakeholders and the public.

Lastly, current debates on sustainable food systems identify meat consumption and animal products as key issues for our environmental footprint. However, our results show that PDO-certified meat production can coexist with environmentally valuable landscape features. Instead of treating meat from all origins identically, we believe that PDO-certified production systems can be role models for a 'less but better meat' mindset. That, in turn, would require implementing conditions for PDO certification (and potentially CAP subsidies) to manage grazing systems sustainably: Providing ecosystem services, maintaining habitat

structures as well as cultural landscape features, contributing to public health, and reducing greenhouse gas emissions should become more profitable. Considering the meat- and cheese-dominated past of the PDO label, the role of plant-based PDOs could also be strengthened within the GI scheme. In cases where low degrees of processing lead to little added value, this could be increased by highlighting the use of PDO-labeled raw products as ingredients. Thus, further processed products could receive an additional label indicating the partial use of a PDO.

If used and adapted wisely, we believe that Geographical Indications in general, and PDOs, in particular, can be important elements for both conserving traditional heritage and promoting sustainable innovation. Thus, we suggest maintaining and developing PDOs as income sources for structurally weak rural regions while at the same time using their potential for contributing to the United Nations Sustainable Development Goals.

Data availability

The original data on which the results of this study are based (including the PDO score datasets, and the social-ecological indicator datasets), can be accessed through the Zenodo repository under the following link: https://doi.org/10.5281/zenodo.6483031

References Chapter 3

agri71.fr (2021) Comté : vers un record de production avec environ 70.000 tonnes sur 2020-2021. https://www.agri71.fr/articles/02/03/2021/Comte-vers-un-record-de-production-avec-environ-70-000-tonnes-sur-2020-2021-53148/. Accessed 11 Oct 2021

Belletti G, Marescotti A (2011) Origin Products, Geographical Indications and Rural Development. In: Sylvander B, Barham E (eds) Labels of origin for food. Local development, global recognition. CABI, Cambridge, pp 75–91

Belletti G, Marescotti A, Sanz-Cañada J, Vakoufaris H (2015) Linking protection of geographical indications to the environment: Evidence from the European Union olive-oil sector. Land Use Policy 48: 94–106. 10.1016/j.landusepol.2015.05.003

Bennett N, Whitty TS, Finkbeiner EM, Pittman J, Bassett H, Gelcich S, Allison EH (2018) Environmental Stewardship: A Conceptual Review and Analytical Framework. Environmental management. 10.31230/osf.io/tb85n

Bérard L, Marchenay P (2006) Local products and geographical indications: taking account of local knowledge and biodiversity. Int Social Science J 58 (187): 109–116. 10.1111/j.1468-2451.2006.00592.x

Berriet-Solliec M, Lataste F, Lépicier D, Piguet V (2018) Environmentally and socially beneficial outcomes produced by agro-pastoral systems in the Cévennes National Park (France). Land Use Policy 78: 739–747. 10.1016/j.landusepol.2018.07.033

Blondel J (2006) The 'Design' of Mediterranean Landscapes: A Millennial Story of Humans and Ecological Systems during the Historic Period. Hum Ecol 34 (5): 713–729. 10.1007/s10745-006-9030-4

Bonaccio M, Iacoviello L, Donati MB, Gaetano G de (2021) The tenth anniversary as a UNESCO world cultural heritage: an unmissable opportunity to get back to the cultural roots of the Mediterranean diet. Eur. J. Clin. Nutr. 10.1038/s41430-021-00924-3

Bouwma I, Zinngrebe Y, Runhaar H (2019) Nature Conservation and Agriculture: Two EU Policy Domains That Finally Meet? In: Dries L, Heijman W, Jongeneel R, Purnhagen K, Wesseler J (eds) EU Bioeconomy Economics and Policies: Volume 2, vol 56. Palgrave Macmillan, Cham, pp 153–175. 10.1007/978-3-030-28642-2_9

Bruno D, Sorando R, Álvarez-Farizo B, Castellano C, Céspedes V, Gallardo B, Jiménez JJ, López MV, López-Flores R, Moret-Fernández D, Navarro E, Picazo F, Sevilla-Callejo M, Tormo J,

Vidal-Macua JJ, Nicolau JM, Comín FA (2021) Depopulation impacts on ecosystem services in Mediterranean rural areas. Ecosystem Services 52: 101369. 10.1016/j.ecoser.2021.101369

Bugalho MN, Caldeira MC, Pereira JS, Aronson J, Pausas JG (2011) Mediterranean cork oak savannas require human use to sustain biodiversity and ecosystem services. Front. Ecol. Environ. 9 (5): 278–286. 10.1890/100084

Chacón-Vozmediano JL, Martínez-Gascueña J, Ramos MC (2021) Projected effects of climate change on Tempranillo and Chardonnay varieties in La Mancha Designation of Origin. Agron. Sustainable Dev. 41 (2). 10.1007/s13593-021-00672-5

clal.it (2021) CLAL - Production volumes of the Italian PDO Cheeses. https://www.clal.it/en/?section=formaggi_dop. Accessed 11 Oct 2021

Clark LF, Kerr WA (2017) Climate change and terroir: The challenge of adapting geographical indications. J World Intellect Prop 20 (3-4): 88–102. 10.1111/jwip.12078

dairyreporter.com (2021) Everything you wanted to know about Feta. https://www.dairyreporter.com/Article/2020/01/03/Everything-you-wanted-to-know-about-Feta. Accessed 11 Oct 2021

Dias FS, Bugalho MN, Rodríguez-González PM, Albuquerque A, Cerdeira JO (2015) Effects of forest certification on the ecological condition of Mediterranean streams. J. Appl. Ecol. 52 (1): 190–198. 10.1111/1365-2664.12358

Egea P, Pérez y Pérez L (2016) Sustainability and multifunctionality of protected designations of origin of olive oil in Spain. Land Use Policy 58: 264–275. 10.1016/j.landusepol.2016.07.017

Escribano M, Gaspar P, Mesias FJ (2020) Creating market opportunities in rural areas through the development of a brand that conveys sustainable and environmental values. Journal of Rural Studies 75: 206–215. 10.1016/j.jrurstud.2020.02.002

European Commission (2019a) A European Green Deal. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en. Accessed 11 Oct 2021

European Commission (2019b) Organic farming in the EU. A fast growing sector. Brussels

European Commission (2020) Study on economic value of EU quality schemes, geographical indications (GIs) and traditional specialities guaranteed (TSGs). Final Report. Brussels. 10.2762/396490

European Commission (2021a) eAmbrosia the EU geographical indications register. https://ec.europa.eu/info/food-farming-fisheries/food-safety-and-quality/certification/quality-labels/geographical-indications-register/. Accessed 11 Oct 2021

European Commission (2021b) Farm to Fork Strategy. https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en. Accessed 11 Oct 2021

European Council (1992) Council Regulation (EEC) No 2081/92. of 14 July 1992 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. Brussels

European Council (2012) Regulation (EU) No 1151/2012 of the European Parliament and of the Council of 21 November 2012 on quality schemes for agricultural products and foodstuffs. L 343

Flinzberger L, Zinngrebe Y, Plieninger T (2020) Labeling in Mediterranean agroforestry landscapes: a Delphi study on relevant sustainability indicators. Sustainability Sci. 15 (5): 1369–1382. 10.1007/s11625-020-00800-2

Fournier L-S, Michel K (2017) Mediterranean Food as Cultural Property? Towards an Anthropology of Geographical Indications. In: May S, Sidali KL, Spiller A, Tschofen B (eds) Taste | Power | Tradition. Göttingen University Press, Göttingen. 10.17875/gup2017-1004

García-Martín M, Torralba M, Quintas-Soriano C, Kahl J, Plieninger T (2021) Linking food systems and landscape sustainability in the Mediterranean region. Landscape Ecol. 36 (8): 2259–2275. 10.1007/s10980-020-01168-5

Ghazoul J (2013) Landscape Labeling: Combining certification with ecosystem service conservation at landscape scales. In: Koellner T (ed) Ecosystem Services and Global Trade of Natural Resources. Routledge, pp 242–261. 10.4324/9780203816639

Higgins DM (2018) Brands, Geographical Origin, and the Global Economy. Cambridge University Press. 10.1017/9781139507059

Kizos T, Koshaka R, Penker M, Piatti C, Vogl CR, Uchiyama Y (2017) The governance of geographical indications. Br. Food J. 119 (12): 2863–2879. 10.1108/BFJ-01-2017-0037

Kizos T, Plieninger T, Schaich H, Petit C (2012) HNV permanent crops: olives, oaks, vineyards and fruit trees. In: Oppermann R, Beaufoy G, Jones G (eds) High Nature Value Farming in Europe. Verlag Regionalkultur, Ubstadt-Weiher, pp 70–84

Lamarque P, Lambin EF (2015) The effectiveness of marked-based instruments to foster the conservation of extensive land use: The case of Geographical Indications in the French Alps. Land Use Policy 42: 706–717. 10.1016/j.landusepol.2014.10.009

Levers C, Müller D, Erb K, Haberl H, Jepsen MR, Metzger MJ, Meyfroidt P, Plieninger T, Plutzar C, Stürck J, Verburg PH, Verkerk PJ, Kuemmerle T (2018) Archetypical patterns and trajectories of land systems in Europe. Reg. Environ. Change 18 (3): 715–732. 10.1007/s10113-015-0907-x

Lomba A, Moreira F, Klimek S, Jongman RHG, Sullivan C, Moran J, Poux X, Honrado JP, Pinto-Correia T, Plieninger T, McCracken DI (2019) Back to the future: rethinking socioecological systems underlying high nature value farmlands. Front. Ecol. Environ. 29: 1006. 10.1002/fee.2116

Lusk JL, Briggeman BC (2009) Food Values. Agricultural & Applied Economics Association 91 (1): 184–196. 10.1111/j.1467-8276.2008.01175.x

Malek Ž, Verburg PH, R Geijzendorffer I, Bondeau A, Cramer W (2018) Global change effects on land management in the Mediterranean region. Global Environ. Change 50: 238–254. 10.1016/j.gloenvcha.2018.04.007

Mann C, Plieninger T (2017) The potential of landscape labeling approaches for integrated landscape management in Europe. Landscape Res. 42 (8): 904–920. 10.1080/01426397.2017.1335863

Navarro A, López-Bao JV (2019) EU agricultural policy still not green. Nat. Sustainability 2 (11): 990. 10.1038/s41893-019-0424-x

Padilla M, Capone R, Palma G (2012) Sustainability of the foodchain from field to plate: The vase of the Mediterranean diet. In: Burlingame BA, Dernini S (eds) Sustainable diets and biodiversity. Directions and solutions for policy, research and action. FAO, Rome, pp 230–240

Parga-Dans E, González PA, Enríquez RO (2020) The social value of heritage: Balancing the promotion-preservation relationship in the Altamira World Heritage Site, Spain. Journal of Destination Marketing & Management 18: 100499. 10.1016/j.jdmm.2020.100499

Pe'er G, Bonn A, Bruelheide H, Dieker P, Eisenhauer N, Feindt PH, Hagedorn G, Hansjürgens B, Herzon I, Lomba Â, Marquard E, Moreira F, Nitsch H, Oppermann R, Perino A, Röder N, Schleyer C, Schindler S, Wolf C, Zinngrebe Y, Lakner S (2020) Action needed for the EU Common Agricultural Policy to address sustainability challenges. People Nat. 10.1002/pan3.10080

Pe'er G, Zinngrebe Y, Moreira F, Sirami C, Schindler S, Müller R, Bontzorlos V, Clough D, Bezák P, Bonn A, Hansjürgens B, Lomba A, Möckel S, Passoni G, Schleyer C, Schmidt J, Lakner S (2019) A greener path for the EU Common Agricultural Policy. Science (New York, N.Y.) 365 (6452): 449–451. 10.1126/science.aax3146

Plieninger T, Bieling C (2013) Resilience-Based Perspectives to Guiding High-Nature-Value Farmland through Socioeconomic Change. Ecol. Soc. 18 (4). 10.5751/ES-05877-180420

Plieninger T, Flinzberger L, Hetman M, Horstmannshoff I, Reinhard-Kolempas M, Topp E, Moreno G, Huntsinger L (2021) Dehesas as high nature value farming systems: a social-ecological synthesis of drivers, pressures, state, impacts, and responses. Ecol. Soc. 26 (3). 10.5751/ES-12647-260323

Plieninger T, Hartel T, Martín-López B, Beaufoy G, Bergmeier E, Kirby K, Montero MJ, Moreno G, Oteros-Rozas E, van Uytvanck J (2015) Wood-pastures of Europe: Geographic coverage, social–ecological values, conservation management, and policy implications. Biol. Conserv. 190: 70–79. 10.1016/j.biocon.2015.05.014

Plieninger T, Torralba M, Hartel T, Fagerholm N (2019) Perceived ecosystem services synergies, trade-offs, and bundles in European high nature value farming landscapes. Landscape Ecol. 10 (4): 439. 10.1007/s10980-019-00775-1

Quiñones-Ruiz XF, Forster H, Penker M, Belletti G, Marescotti A, Scaramuzzi S, Broscha K, Braito M, Altenbuchner C (2018) How are food Geographical Indications evolving? – An analysis of EU GI amendments. Br. Food J. 120 (8): 1876–1887. 10.1108/BFJ-02-2018-0087

Quiñones-Ruiz XF, Penker M, Belletti G, Marescotti A, Scaramuzzi S, Barzini E, Pircher M, Leitgeb F, Samper-Gartner LF (2016) Insights into the black box of collective efforts for the registration of Geographical Indications. Land Use Policy 57: 103–116. 10.1016/j.landusepol.2016.05.021

Quintas-Soriano C, Buerkert A, Plieninger T (2022) Effects of land abandonment on nature contributions to people and good quality of life components in the Mediterranean region: A review. Land Use Policy 116: 106053. 10.1016/j.landusepol.2022.106053

Raimondi V, Curzi D, Arfini F, Olper A, Aghabeygi M (2018) Evaluating Socio-Economic Impacts of PDO on Rural Areas. Conegliano. 10.22004/ag.econ.275648

Raymond CM, Bieling C, Fagerholm N, Martin-Lopez B, Plieninger T (2016) The farmer as a landscape steward: Comparing local understandings of landscape stewardship, landscape values, and land management actions. Ambio 45 (2): 173–184. 10.1007/s13280-015-0694-0

Schebesta H, Candel JJL (2020) Game-changing potential of the EU's Farm to Fork Strategy. Nat. Food 1 (10): 586–588. 10.1038/s43016-020-00166-9

Schröter D, Cramer W, Leemans R, Prentice IC, Araújo MB, Arnell NW, Bondeau A, Bugmann H, Carter TR, Gracia CA, La Vega-Leinert AC de, **Erhard M, Ewert F, Glendining M, House JI, Kankaanpää S, Klein RJT, Lavorel S, Lindner M, Metzger MJ, Meyer J, Mitchell TD, Reginster I, Rounsevell M, Sabaté S, Sitch S, Smith B, Smith J, Smith P, Sykes MT, Thonicke K, Thuiller W, Tuck G, Zaehle S, Zierl B** (2005) Ecosystem service supply and vulnerability to global change in Europe. Science (New York, N.Y.) 310 (5752): 1333–1337. 10.1126/science.1115233

Scolozzi R, Morri E, Santolini R (2012) Delphi-based change assessment in ecosystem service values to support strategic spatial planning in Italian landscapes. Ecol. Indic. 21: 134–144. 10.1016/j.ecolind.2011.07.019

Spiller A, Tschofen B (2017) Taste – Power – Tradition. Placing Geographical Indications on an Interdisciplinary Agenda. In: May S, Sidali KL, Spiller A, Tschofen B (eds) Taste | Power | Tradition. Göttingen University Press, Göttingen. 10.17875/gup2017-1004

Strohbach MW, Kohler ML, Dauber J, Klimek S (2015) High Nature Value farming: From indication to conservation. Ecological Indicators 57: 557–563. 10.1016/j.ecolind.2015.05.021

Underwood E (2014) Farming for Natura 2000. Guidance on how to support Natura 2000 farming systems to achieve conservation objectives, based on Member States good practice experiences. 10.2779/85823

Vakoufaris H, Belletti G, Kizos T, Marescotti A (2014) Protected Geographical Indications and the landscape: towards a conceptual framework. Meeting of the Workshops for the implementation of the European Landscape Convention: 'Sustainable Landscapes and Economy: on the inestimable natural and human value of the landscape'. Unpublished. Urgup

van Ittersum K, Meulenberg MTG, van Trijp HCM, Candel, Math J. J. M. (2007) Consumers' Appreciation of Regional Certification Labels: A Pan-European Study. J. Agric. Econ. 58 (1): 1–23. 10.1111/j.1477-9552.2007.00080.x

van Vliet J, Groot HL de, **Rietveld P, Verburg PH** (2015) Manifestations and underlying drivers of agricultural land use change in Europe. Landscape Urban Plann. 133: 24–36. 10.1016/j.landurbplan.2014.09.001

Vandecandelaere E, Teyssier C, Barjolle D, Jeanneaux P, Fournier S, Beucherie O (2018) Strengthening sustainable food systems through geographical indications. An analysis of economic impacts. Rome

Chapter 4
Characteristic agri-food landscapes host geographical indications

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Abstract

Implementing the European Green Deal and transforming agricultural practices requires a wider and amplified policy toolbox. As many sustainability considerations are context-dependent, there is a need for instruments, which take individual characteristics of production landscapes into account. Food products with a particularly strong relationship to their landscape of origin can be marketed under the "Protected Designation of Origin" label (PDO). In this article, we analyze synergies between PDO production and regional sustainable development by assessing to what extent social-ecological landscape characteristics appear in landscapes with PDO-labeled food production systems. Building upon 12 social-ecological variables we defined three landscape characteristics influential for the presence of PDOs by using a principal component analysis. By running regression models combining those characteristic landscapes with the spatial distribution of PDO certification we were able to explore linkages between landscapes and products. Additionally, a geographically weighted regression delivered insights into the regional differences and product-specific relationships throughout the EU countries. Overall, we could prove the assumed positive correlation between PDO production and ecologically valuable landscapes. Further, we showed that mostly meat PDOs coincide with landscapes influenced by structural change, while cheese PDOs are not well captured by our models despite their large number. We can conclude that PDOs have the potential to jointly support conservation and rural development, especially when they would be tied to sustainable management standards in the future.

4.1 Introduction

Agricultural food products are linked to the social and ecological conditions of the production systems they originate from (Andersson et al., 2015; Oteros-Rozas et al., 2019). Some prominent food products even constitute central characteristic elements of particular iconic landscapes, bearing a deep relation with the local traditions of landscape stewardship (Mann and Plieninger, 2017). While both the European Green Deal and its Farm to Fork strategy aim for a sustainable transformation of European agricultural landscapes, the green architecture of EU policies is still limited and ineffective (Pe'er et al., 2020). Aside from the Common Agricultural Policy (CAP), private labels and value chain-based incentives represent an unused potential for supporting sustainable production. The EU has developed a "Geographical Indications" scheme (GI), providing the option to register products under the "Protected Designation of Origin" (PDO) label or the "Protected Geographic Indication" (PGI) label (European Council, 1992, 2012) and thus legally protect their names. The PDO label certifies the highest standard for products to be linked with the geography, landscape, traditions, and food culture of their production system, making them a landscape label (Ghazoul et al., 2011). PDOs are widespread over European agricultural landscapes, with a particularly high representation in Mediterranean countries (European Commission, 2020b). Without being designed for this purpose, PDOs were found suitable for supporting sustainable forms of production, such as agroforestry systems (Flinzberger et al., 2020). Uneven distribution patterns of PDOs across Europe however indicate that potential synergies between PDO systems and sustainability efforts vary across product types, geographical location, or social-ecological context.

Definitions of PDOs include strict spatial requirements for producing and processing the product, as well as descriptions of how products and traditional agricultural landscapes are connected (Kizos and Vakoufaris, 2009). The associated EU regulation states the following requirements for any PDO: "[…] "designation of origin" is a name which identifies a product: (a) originating in a specific place, region or, in exceptional cases, a country; (b) whose quality or characteristics are essentially or exclusively due to a particular geographical environment with its inherent natural and human factors; and (c) the production steps of which all take place in the defined geographical area" (European Council, 2012). Thus, besides its function as protection of intellectual and cultural property (May, 2016), the PDO label is also meant to transmit landscape values to consumers (Vakoufaris et al., 2014). Meanwhile, the requirements for PGIs are less strict. Product characteristics are less tightly bound to the geographic environment, animal feed can be sourced in distant regions or countries, with only certain production or processing steps being linked to the designated area. Hence, we focus this study solely on PDO products due to their stronger linkage with landscape characteristics. In terms of causal relationships, it is difficult to determine whether agricultural management practices such as PDOs have shaped the landscapes or vice versa. Instead, a co-evolutionary process (Quiñones-Ruiz et al., 2018) between landscapes and products appears to be sensible.

The potential of PDOs to contribute to sustainable development will depend on their ability to induce and support suitable management practices. While some characteristics of successful PDO production have been described as inherently sustainable (Lamarque and Lambin, 2015; Egea and Pérez y Pérez, 2016), they were not designed to be sustainability labels in the first place. Existing studies on PDOs have mainly focused on analyzing the cultural and economic history of "Geographical Indications" (Clark and Kerr, 2017; Fournier and Michel, 2017; Török and Moir, 2018). Despite these efforts, we still lack a better understanding of how individual product types interact with landscapes of origin and to what extent they can assure sustainability safeguards. The potential of the PDO scheme for contributing to the implementation of EU's sustainable development targets, such as those indicated in the European Green Deal or its Farm to Fork strategy (European Commission, 2020a), will depend on its ability to actively shape the underlying landscape-production system (Tashiro et al., 2019). To assess the PDO's potential for supporting sustainability, we need to better understand the synergies between social-ecological trajectories in PDO-certified landscapes and different dimensions of sustainability.

To this end, this article analyses how different PDO types are linked to certain social-ecological landscape indicators. For this purpose, we have used a spatially explicit dataset of all 638 food PDOs registered across the EU and linked them to their location on the NUTS-3 level. In addition, we have selected 12 social-ecological indicators available on the same scale, representing environmental and social-economic states and trends. We then performed a principal component analysis and identified three distinguishable social-ecological landscape types (landscapes of high ecologic value, landscapes characterized by structural change, and landscapes of high cultural-touristic value). Based on these landscape types, considering the PDOs' geographical distribution and splitting them up into four different product categories (meat, cheese, oils, fresh crops), we calculated multi-linear hurdle regression models. These models allowed us to assess to what extent specific PDOs correlate with the predefined landscape types, distinguishing between the Mediterranean and non-Mediterranean countries. Finally, we analyzed under-performing and over-performing regions in terms of PDO production with regard to the expected distribution from a geographically weighted regression model.

Our research design was based on the following three assumptions about the leverage points that PDO production offers for sustainable landscape management:

1- Landscapes providing high ecological values have a stronger potential for producing PDO-labeled quality food products.
2- PDO products are associated with rural, less populated regions and can act as entry points for rural development strategies.
3- Given the first two hypotheses, we assume that PDOs are suitable tools to combine the ecological and social aspects of sustainable landscape management.

To examine these assumptions, we apply a holistic understanding of social-ecological sustainability. In the methods section, we explain how we have derived three landscapes of distinct characteristics by using a principal component analysis (PCA), and how we build a regression model from those landscape types together with the spatial PDO data. In the results, we present the outcome of our regression models and the quality of those models, including an additional geographically weighted model. Finally, we discuss the implications of those results for using PDO products successfully within the EU's agriculture policy and conclude with a recommendation for initiating a sustainability-oriented PDO+ label.

4.2 Materials and Methods

A dataset of European PDO products

In preparation for this research, we mapped the geographical extent of all European food products labeled under the "Protected Designation of Origin" (PDO). The original data was retrieved from the eAmbrosia database of the European Commission, where the geographical extent of each product had to be extracted from the legal documents (PDF text files). We included all 638 food PDOs registered by 31st July 2020 but did not include wine products. As explained above, we consciously decided to not include any PGI products, because their production is not linked closely enough to a certain landscape. Due to practical reasons and data availability, the extent of all PDOs was mapped at the local NUTS-3 scale (EU's territorial units for statistics). Many statistical datasets at EUROSTAT are available at this scale or the regional NUTS-2 scale, but rarely at finer scales. Hence, for merging a dataset of PDO data and social-ecological indicators (see below), suitable for a multi-linear regression, the NUTS-3 scale was the optimal choice.

The final dataset revealed the geographical extent of any PDO product using the boundaries of the European NUTS-3 regions. Counting the number of PDO products linked to any given NUTS-3 region we calculated the so-called "PDO-score" for all EU NUTS-3 regions (Figure 1). This means that PDOs with geographical areas larger than a single NUTS-3 region were added to the score in each corresponding NUTS-3 region (original PDO data in Supplementary Material). As presented in Table 1 and visualized in Figure 1, the PDOs are not evenly distributed over Europe, but eight Mediterranean EU countries (PT, ES, FR, IT, SI, HR, GR, CY) are home to 542 of 638 PDO-labeled products. Also, in terms of product types, the number of registered PDOs varies significantly. Five major product categories account for the majority (85%) of all registered PDOs: "fresh meat," "processed meat," "cheese, oils and fats," and "fruits, vegetables, and cereals." Both meat categories were merged into one sample and are further referred to as "meat PDOs," while the category of "fruits, vegetables and cereals" is called "fresh crops" from here on.

Table 1 Categories of PDOs according to the European eAmbrosia database with separate numbers for the Mediterranean and non-Mediterranean countries, data extracted by 31st July 2020. Two meat categories (fresh and processed) were merged into one.

	Total EU PDOs	Mediter. PDOs	non-Mediter. PDOs
Fresh and processed meat	80	67	13
Cheeses	192	160	32
Oils & fats	118	116	2
Fruits, vegetables and cereals	151	130	21
Other products of animal origin	37	31	6
Fresh fish	12	5	7
Other products (spices, etc.)	30	20	10
All other categories	18	13	5
Total	**638**	**542**	**96**

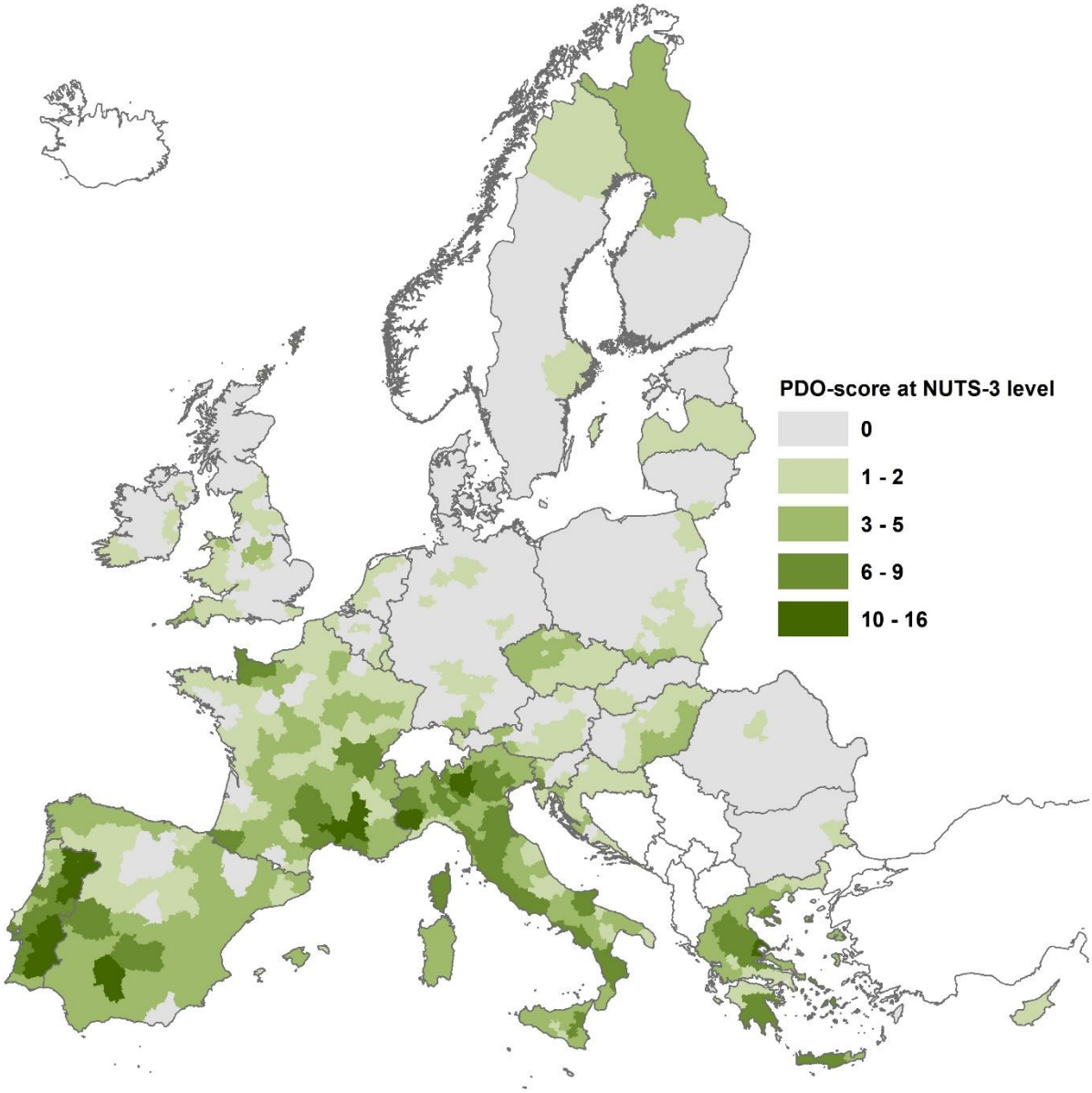

Figure 4.1 Range of the PDO-score across all NUTS-3 regions in Europe. The PDO-score represents the number of PDO products that are allowed to be produced in any given NUTS-3 region. The score ranges from zero to 16 with easily recognizable hotspots in some Mediterranean countries.

Variables explaining hotspots of PDO production in Europe

To approach our hypotheses about the landscape relations of PDOs we selected 12 variables covering a broad range of social-ecological characteristics. The variables covered indicators for ecological values, the state of conservation, cultural and touristic values, demographic situation and development, socio-economic aspects, and average farm sizes. The data was retrieved mainly from the official databases of EUROSTAT or EEA (Table 2).

Table 4.2 List of all original social-ecological variables used for the PCA analysis. The data of variables marked with * was available on the NUTS-2 level and scaled to NUTS-3.

Social-ecological variables	Range	Unit	Source	Year
High Nature Value Farmland	0 - 81.0	*% of total area*	EEA: eea.europa.eu/.../high-nature-value-farmland	2012
Natura 2000	0 - 75.0	*% of total area*	EEA: eea.europa.eu/data-and-maps/data/natura-11	2019
Corine landcover richness	0 - 41.0	*no. of classes*	COPERNICUS: land.copernicus.eu/.../corine	2018
Semi-natural farmland	0 - 53.9	*% of total area*	COPERNICUS: land.copernicus.eu/.../corine	2018
Tourism beds	0 - 367,400	*no. of beds*	EUROSTAT: eurostat.ec.europa.eu/...tour_cap	2011
UNESCO World Heritage sites	0 - 9	*no. of sites*	UNESCO/WHC: whc.unesco.org/en/syndication	2013
Population density	2 - 21,000	*pop. per km²*	EUROSTAT: eurostat.ec.europa.eu/...demo_r_d	2018
Median age	18.1 - 55.5	*years*	EUROSTAT: eurostat.ec.europa.eu/...demo_r_pjan	2019
5-year migration rate (2013-18)	-14.5 - 17.0	*% of population*	EUROSTAT: eurostat.ec.europa.eu/...demo_r_pjangrp	2018
GDP per capita	3,100 - 501,600	*Euros*	EUROSTAT: eurostat.ec.europa.eu/...nama_10r_3gdp	2016
Youth Unemployment* (15-24 a)	0 - 30.1	*% of population*	EUROSTAT: eurostat.ec.europa.eu/...fst_r_lfu	2019
Average farm size*	0 - 274	*ha UAA[1]*	EUROSTAT: eurostat.ec.europa.eu/...aareg	2016

The proportion of "High Nature Value Farmland" (HNVF) and the share of NATURE 2000 areas were used as indicators for a high environmental value as they reflect efforts of nature conservation. The number of different Corine landcover classes ("Corine landcover richness") and the share of semi-natural farmland (three selected Corine classes: "agroforestry," "agricultural land with nature areas," and "complex agricultural patterns") were used as indicators for a diverse and multifunctional agricultural landscape. The numbers of "tourism beds" and "UNESCO World Heritage sites" were selected to reflect the cultural-touristic value of a given region. "Population density," "median age," and a "5-year migration rate" (2013–2018) were chosen as indicators for the demographic trend. The two indicators "regional GDP per capita" and "youth unemployment" (between age 15 and 24) were selected to represent the economic situation. Finally, we included the "average farm size" as a regional indicator for the level of industrialization of the agricultural sector. The environmental and cultural variables are proven indicators within the context of sustainable landscape management and conservation. Considering the socio-demographic variables, they are even more frequently used in various kinds of socio-economic assessments.

Where possible, we used data provided at the NUTS-3 level to match the spatial scale of the mapped PDO products later on. Data available only at the NUTS-2 level (youth unemployment, and average farm size) was scaled down, assuming all subordinated NUTS-3 areas to have the same value as the higher-level NUTS-2 region. A larger set of social-ecological variables has been tested for their direct correlation with the presence of PDO products. From this pre-test, only variables that showed a relevant and significant correlation with PDO presence were chosen. For example, the "organic farming" indicator was not significantly correlated and thus was not used in this regression analysis.

Extraction and interpretation of relevant factors

We performed a principal component analysis (PCA) in 'Statistica' to reduce the complexity of the initial set of variables. The explorative PCA for all EU states, including 12 social-ecological variables, revealed three components that represented more than half of the variance within the original variables. By

considering components with an eigenvalue above one, the three components combined explained 53% of the total variance. This step – the extraction of relevant components – can be seen as a form of correlation analysis, when treating the component loadings of each variable as the correlation of the component with the original variable (Table 3). From the PCA we found which original variables were particularly "correlated" with which of the newly computed components – either negative or positive – and which variables jointly loaded onto the same component. Hence, based on those combinations of positive and negative component loadings we interpreted the three components as three distinguishable social-ecological landscapes of different characteristics.

Table 4.3 Loadings for three components (C1–C3), that were derived from a principal component analysis of 12 social-ecological variables. High positive loadings are marked green, and high negative loadings are marked orange, always with regard to the loadings within one component.

	Component Loadings		
	Component 1	**Component 2**	**Component 3**
High Nature Value Farming	0.72	-0.17	-0.13
Natura 2000 areas	0.59	0.03	0.10
Landcover Richness (CLC)	0.75	-0.14	0.32
Semi-natural farmland	0.58	-0.22	-0.28
UNESCO sites	0.29	-0.41	0.49
Tourism Beds	0.26	-0.41	0.61
Population Density	-0.53	-0.49	-0.14
Median age	0.34	0.69	0.28
5-year migration rate	-0.62	-0.40	0.20
GDP per Capita	-0.58	-0.34	0.21
Average farm size (km²)	-0.30	0.50	0.47
Youth unemployment 15-24	0.61	-0.36	-0.19
Eigenvalue of the component	3.49	1.81	1.26
Variance explained (%)	29.07	15.09	5.30

Regression models for count and zero-inflated data

For testing the effect of the aforementioned components on the number of PDOs per NUTS-3 region, we employed regression models. Each region represented one observation (n = 1,348). As our dependent variables were count data and displayed an excess of zero values, we used regression models specifically designed for this type of data called "hurdle models" (similar to generalized linear models [GLM]). Hurdle models combine two model types. The "zero-model" predicts the probability of occurrence of any count > 0 with a logistic regression model (GLM with logit link function). The "count-model" is a zero truncated regression model for the number of counts based on all observations with counts > 0. The predicted number of counts is yielded by combining (multiplying) the predicted probability of occurrence from the zero-models (the "hurdle") with the predicted counts of the count-models (Mullahy, 1986; Cameron and Trivedi, 2013). For the count-model, we used a GLM with a negative binomial error distribution to account for over-dispersed count data in our data set.

As predictor variables in our models, we used the component scores (C1, C2, C3) from the PCA (see geographically weighted regression). The components represented different complex landscape characteristics derived from the correlation structure of the 12 initial socio-ecological variables. The component scores were standardized prior to the regression analyses to make regression coefficients better comparable with respect to effect sizes. As all components were derived from a PCA, they were uncorrelated, hence multicollinearity was no problem.

Additionally, we included a dichotomous covariable MEDITERRANEAN indicating whether a region was situated in a Mediterranean country (1, n = 347) or not (0, n = 1,001). To account for the possibility of modeling different responses of PDOs to the components in the Mediterranean vs. non-Mediterranean regions, we included the interactions between MEDITERRANEAN and the component variables C1–3. We started with a full model containing all components and their interactions with MEDITERRANEAN and subsequently reduced the models by stepwise omitting non-significant interactions or components. Non-significant components were retained if their interactions with MEDITERRANEAN were significant.

We fitted our models with the hurdle() function from the "pscl" package in R (R Core Development Team, 2020). We used maximum likelihood estimation and BFGS iterations for optimization (Zeileis et al., 2008; Jackman, 2020). In multiple linear regression, model fit is usually reported with R squared (R2), calculated from sums of squares. As this does not apply to GLM models with a non-normal error distribution, we calculated the squared correlation coefficient (r) of predicted vs. observed counts as an equivalent measure for the hurdle model fit. Moreover, we calculated the Nagelkerke- (or Cragg-Uhler-) pseudo-R squared-value (Nagelkerke, 1991) to assess the fit of the zero-model alone [function pR2(), package pscl].

We calculated five different regression models: one for the total number of PDOs, and one for each of the four PDO categories. The hurdle() function then estimated the coefficients for the zero model and the count-model separately, which are both relevant for interpretation. The regression coefficients of the zero-model indicate the effect size of the four variables (C1–C3 and covariable MEDITERRANEAN) for having at least one PDO in a given NUTS-3 region. The regression coefficients of the count-model provide information about their effect on the actual numbers of PDOs. The regression coefficient for the covariable MEDITERRANEAN indicates to what extent the presence (zero-model) and number (count-model) of PDOs generally differ between Mediterranean and non-Mediterranean regions, irrespective of the components' effects. A significant component-MEDITERRANEAN interaction indicates that the individual effect of the respective component on PDOs is significantly different between the Mediterranean and non-Mediterranean countries.

Geographically weighted regression

The hurdle regression models helped to understand the influence of the three components on PDOs of different food categories. However, it did not consider the geographic distribution of PDOs in relation to each other. In theory, a regression model would be able to predict the outcome for unknown cases but that was not the intention nor the capacity of the hurdle models' results. Because the hurdle model did not consider the values in a geographical sense (i.e., it does not include the information about a neighboring NUTS-3 region), and because we mapped the entirety of all 638 food PDOs, a predictive model was not what we aimed for by computing the hurdle models. In other words, there was no geographically explicit information about the relation between predicted and observed PDO frequency. To find out if certain types of PDOs were over-represented or under-represented in some regions of Europe, we applied a geographically weighted regression (GWR) in ArcGIS (under /spatial statistics toolbox/modeling spatial relationships). The GWR tool computed a local linear regression – so by using this tool, we traded the hurdle model's ability to deal with zero-inflated data for the benefit of having the geographical information represented within the model. Again, the component scores were used as independent variables, and the PDO score as the dependent variable. The GWR results yielded a local regression model for each NUTS-3 region. From the results, we then checked the local coefficients of determination (R2) which ranged between 0.1 in Northern Europe and 0.7 in the Mediterranean region. But more important we used the standardized residual values (StdResid) for making further interpretations. The standardized residual values were of particular interest because they told the difference between the observation (number of PDOs present) and the models' estimation (how many PDOs were expected to be present). We further used this value to

visualize where PDOs of different food categories are over-represented or under-represented according to the GWR model.

4.3 Results

Interpretation of the principal components

We interpreted the three revealed components in terms of their social-ecological landscape features, based on the variables with strong positive or strong negative loadings (Table 3). The visualizations below (Figures 2–4) showcase NUTS-3 regions that particularly contributed to the positive (highest quintile) or negative (lowest quintile) expressions of the respective component and its underlying interpretation. In order of declining explanatory power, the three components are described as follows:

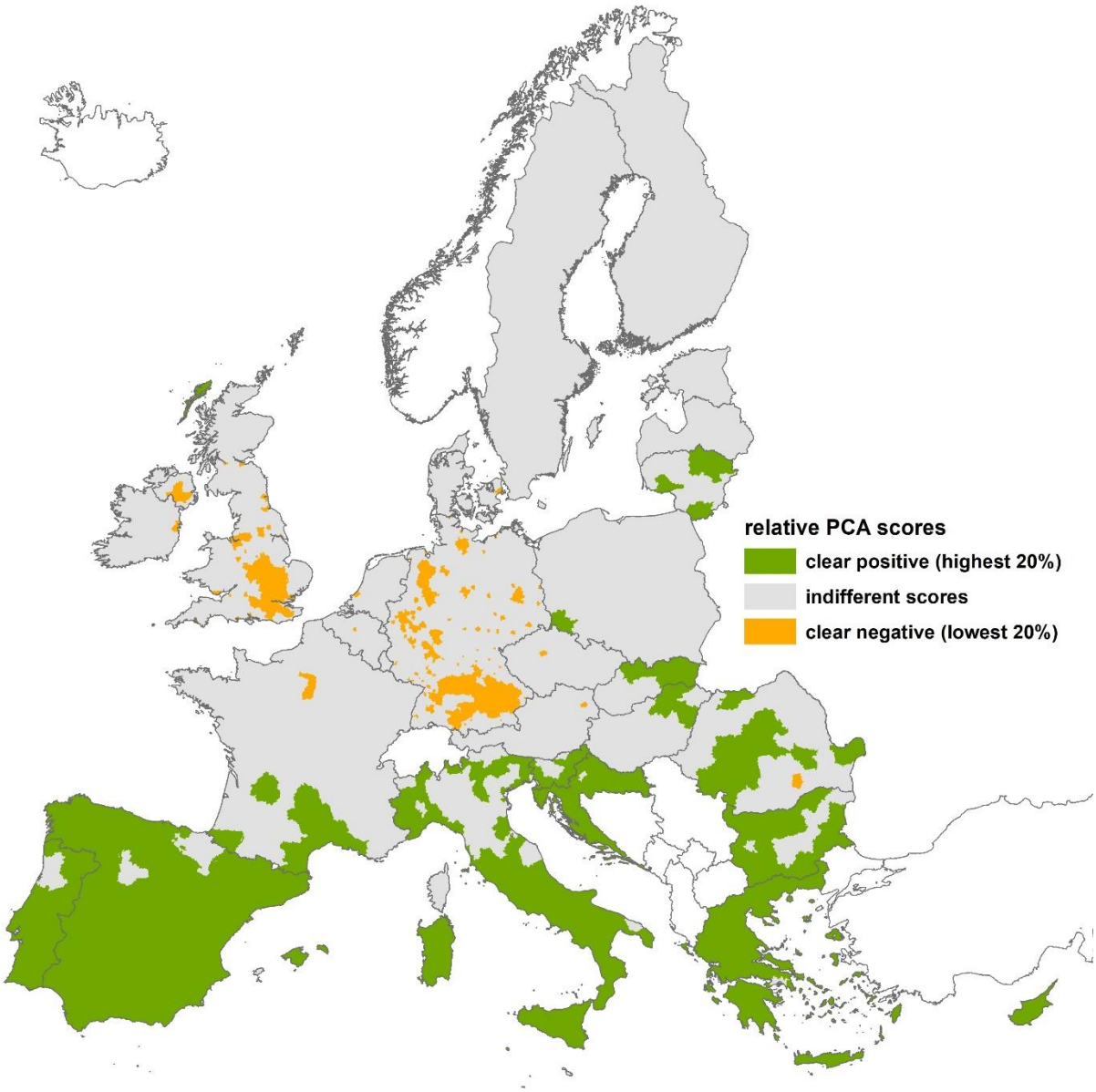

Figure 4.2 Relative scores of the first component, showing NUTS-3 regions that strongly contribute to the positively (green) loaded variables of high ecological values, or negatively (orange) loaded variables of socio-economic aspects, in contrast to the indifferent regions (gray). [negative = 1st quintile; positive = 5th quintile].

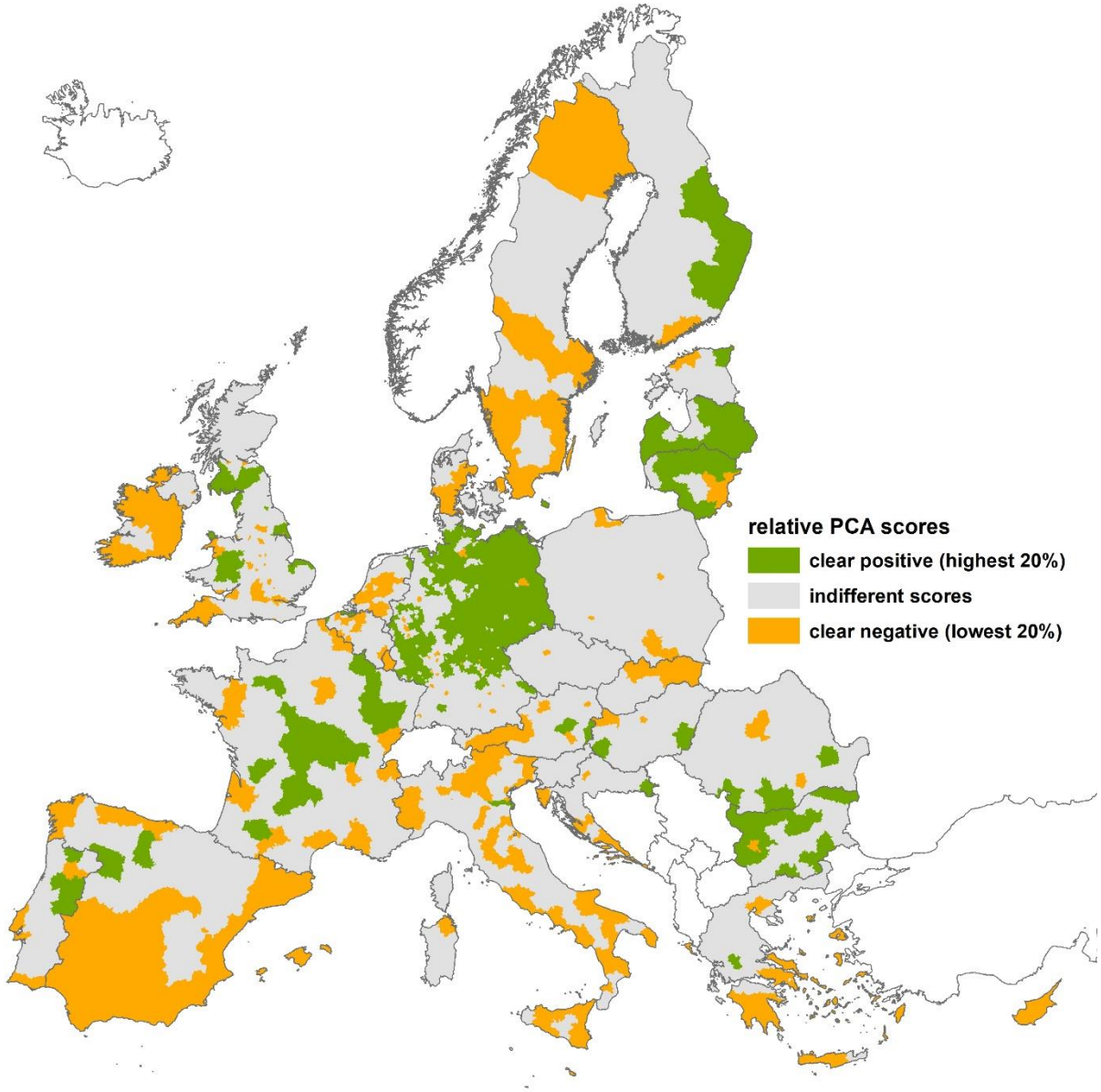

Figure 4.3 Relative scores of the second component, showing NUTS-3 regions that strongly contribute to the positively (green) loaded variables, or negatively (orange), loaded variables related to different aspects of structural change, in contrast to the indifferent regions (gray). [negative = 1st quintile; positive = 5th quintile].

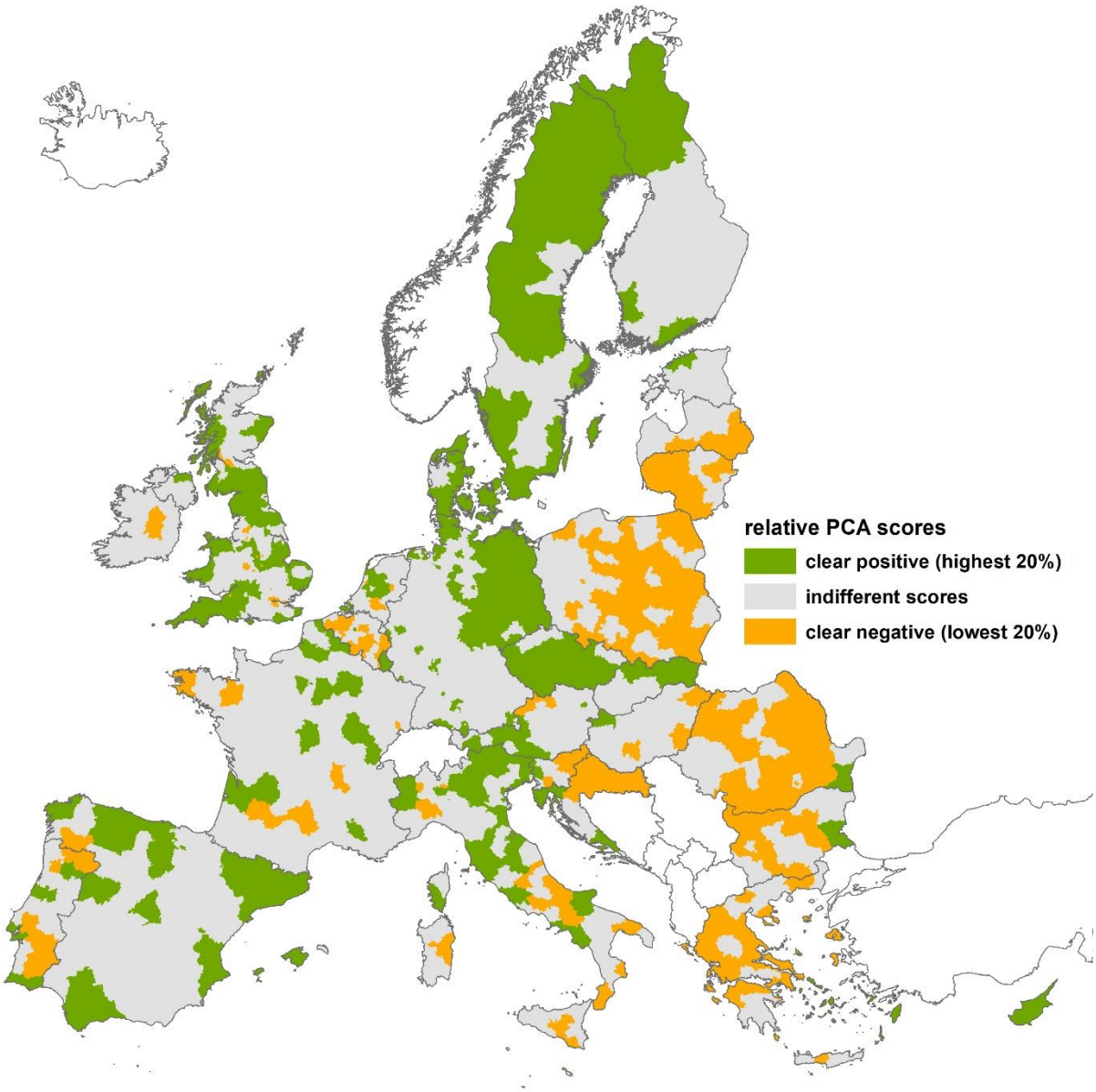

Figure 4.4 Relative scores of the third component, showing NUTS-3 regions that strongly contribute to the positively (green) loaded variables related to high cultural values, or negatively loaded variables (orange), in contrast to the indifferent regions (gray). [negative = 1st quintile; positive = 5th quintile].

Component 1 – Landscapes of high ecological value

Component one explained most of the ecologically relevant values, including the highest component loadings for HNV farming, Natura 2000, landcover richness, and seminatural farmland. At the same time, lower population densities, lower GDP per capita, youth unemployment, and negative migration rates had high loadings on this component too. Thus, we interpreted the first component as landscapes of high ecological values with above-average efforts in nature conservation but situated in socio-economic less favorable regions. Overall, the high ecological values component held the highest explanatory power by explaining more than 25% of the total variance of the dataset. The dark green areas in Figure 2 represented regions that contributed to the positively loaded variables of component one – correlated with high natural and ecological values. Those areas lie almost entirely within the Mediterranean countries. Small areas with strong negative component scores (orange regions) contributed to the negatively loaded variables of the unfavorable socio-economic aspects within component one and occurred mainly in Germany and South UK.

Component 2 – Landscapes influenced by structural change

Component two described the development of demographics and the level of structural change in a given region. High component loadings for median age and average farm sizes occurred along with medium to strong negative loadings for population density and migration rates. The high ecological and cultural values showed almost entirely negative loadings for this component. Therefore, we interpreted the second component as landscapes influenced by structural change (i.e., fewer but larger farms), going along with demographic decline and cultural deprivation. At the same time, the economic aspects were less concerning compared to component one. The structural change component explained 15% of the total variance of the dataset. The orange areas in Figure 3 contributed to the negatively loaded variables of component two, representing the demographic decline aspect of structural change. They were more frequent in the Mediterranean region, Sweden, Ireland, Benelux, and marginal regions of Eastern Europe. Green regions, contributing to the positively loaded variables within component two (associated with the age and farm size aspects of structural change) were mostly situated in the area of former Eastern Germany (GDR), central France, and the Baltic states.

Component 3 – Landscapes of high cultural-touristic values

Component three represented the cultural values of a given region as highlighted by strong positive loadings for UNESCO World Heritage sites, tourism beds, and a diverse landcover. Youth unemployment loaded negatively on this component, although only strong for the Mediterranean sub-sample. Based on that, we interpreted the third component as landscapes of high cultural values which were situated in diverse landscapes with high touristic potentials and associated job opportunities. As the component with the least explanatory power, high cultural-touristic values still explained 12% of the total variance of the dataset. NUTS-3 regions with strong positive scores for component three (dark green areas) contributed to the positively loaded cultural and tourism variables (Figure 4). Logically, they could be found within the typical tourist regions of Europe (e.g., Mallorca, Madrid, Rome, Tuscany, Stockholm, Paris, Tyrol, Harz, South-eastern England, Greek Islands, or Cyprus). The negative aspects of component three appeared to be not relevant for a social-ecological interpretation – also the related component scores extended less far into the negative value range.

Hurdle regressions models against PDO-scores

We extracted the component scores of each case (1,348 NUTS-3 regions overall) and calculated five regression models against the PDO scores of each product category. Thereby, we treated the PDO score as the dependent variable and the component scores of the three landscape types as independent variables, and added the independent covariable "Mediterranean." The hurdle approach differentiated between count-models (number of PDOs), and zero-models (presence of PDOs) for each of the five models. Table 4 displays all significant regression coefficients that resulted from the hurdle regression models (non-significant variables were removed in the final models and coefficients are therefore missing). Especially for component one, and partly for components two and three, the hurdle models revealed some interesting patterns. While the sample size of non-Mediterranean NUTS-3 regions was larger (1,001 regions), the amount of zeros was especially inflated there (771 regions without any registered PDO). On the contrary, in the smaller sample size of Mediterranean NUTS-3 regions (347 regions), only 31 NUTS-3 regions without any registered PDOs occurred. Therefore, despite the smaller sample size, the effect of the covariable "Mediterranean" on PDOs' presence and numbers was significantly stronger than the effects of the variables based on three landscape types (Table 4). By isolating the effect of this covariable, it was possible to draw interesting insights from the regression coefficients (b*) of the other variables. Beyond that, applying the hurdle model as a reduced model with interactions, we found out for which combinations of components and product types there was a significant difference between the effects within, or without the Mediterranean region.

Table 4.4 Results from the hurdle model regression analyses, including a measure of model fit for the predictions of PDO product numbers for each hurdle model (R2 as the squared correlation between observed and predicted numbers), and a measure of model fit of the zero-model for the predicted probability of product occurrence (Nagelkerke R). Given are regression coefficients of reduced models (b*) for both, the count-model and the zero-model of each product category. Empty cells indicate that the respective variable was not significant (p >= 0.05) and was removed from the model. Values printed in bold indicate a significant difference between the Mediterranean and non-Mediterranean regions (i.e. significant interaction).

Models' quality of fit		**all PDOs**		**Meat**		**Cheese**		**Oils**		**Fresh Crops**	
Model R^2 (predicted vs. observed counts)		0.55		0.21		0.34		0.28		0.24	
Zero Model R^2 (Nagelkerke)		0.51		0.33		0.49		0.50		0.34	
Model coefficients *(for count and zero models)*		*count*	*zero*	*count*	*zero*	*count*	*zero*	*count*	*zero*	*count*	*zero*
Covariable 'Mediterranean' (b*)		1.23	3.08		2.45	0.55	3.65		3.01		1.67
C1: landscapes of high ecological value (b*)	non-Medit.	0.31	0.75	0.55	**0.96**			0.64	1.03	0.99	0.82
	Mediterranean				**0.26**						
C2: landscapes characterized by structural change (b*)	non-Medit.	0.11	**-0.41**		**0.10**		**-0.20**		**-1.06**		
	Mediterranean		**0.48**		**0.61**		**0.56**		**-0.20**		
C3: landscapes of high cultural-touristic values (b*)	non-Medit.	0.08	0.29		**-0.28**		0.27				
	Mediterranean				**0.47**						
Number of cases (cases = NUTS-3 areas)		546	1,348	191	1,348	325	1,348	133	1,348	189	1,348

For all EU countries and product types combined, the count-model had a quality-of-fit of $R^2 = 0.55$, which means our model (including the covariable "Mediterranean") explains more than half of the variance in PDO numbers. Also, the corresponding zero-model explained more than half of the variance of PDOs' presence (Nagelkerke $R^2 = 0.51$). For the four different PDO categories, the quality-of-fit ranged between $R^2 = 0.34$ ("fresh crop" PDOs) and $R^2 = 0.21$ (meat PDOs) (Table 4 – upper part). For the PDO sub-categories, the zero-models had an even higher quality-of-fit (Nagelkerke R^2). That means those four models explained the presence or absence of PDOs better than their actual numbers. The covariable

"Mediterranean" appeared to be the strongest overall predictor for the presence of PDOs. The zero-regression coefficients were high for all PDOs combined (b* = 3.08), so being in the Mediterranean made it much more likely to have a PDO product in a NUTS-3 area. The values were similarly high for meat PDOs (b* = 2.45) and "oil and fat" PDOs (b* = 3.01), the highest for cheese PDOs (b* = 3.65), and the lowest for "fresh crop" PDOs (b* = 1.67).

Besides the covariable "Mediterranean," component one was the variable explaining most of the variance in PDO numbers. With a count-regression coefficient of b* = 0.31 for all PDOs combined and even higher count-coefficients for meat (b* = 0.55), "oils and fats" (b* = 0.64), and "fresh crops" (b* = 0.99), landscapes of high ecological values accounted for a significant increase in PDO numbers. The overall count-regression coefficients for component two (b* = 0.11), and component three (b* = 0.08) were smaller but still significant. For component two, the zero-models revealed significant differences between the variable's effect in the Mediterranean and non-Mediterranean countries. For all PDOs combined, PDO products in the non-Mediterranean countries decreased with an increasing C2 component (b* = −0.41, i.e., for landscapes characterized by structural change), while in Mediterranean countries, the number of PDOs even increased (b* = 0.48). A similar pattern with respect to the C2 component showed up for meat, cheese, and "oil fats" PDOs (Table 4).

Looking at the four separate models for the product categories, we found that especially for meat PDOs the zero-model coefficients were significantly different between the Mediterranean and non-Mediterranean regions. While for component one the effect was larger for the non-Mediterranean cases (b* = 0.96) than for the Mediterranean ones (b* = 0.26), it was the opposite for components two and three (Table 4). Further, we found that despite the large total number of PDO products, the number of cheese PDOs could not be explained by the component scores. Only the covariable "Mediterranean" had a significant positive effect on the counts. Further, only a small positive effect of high cultural-touristic values (C3) on PDOs' presence could be found (b* = 0.27), and as reported above, a diverging effect of variable C2 between non-Medit (b* = −0.20) and Medit. areas (b* = 0.56). The count-models for "oil and fat" PDOs as well as "fresh crops" were only significant for variable C1 but reported the highest regression coefficients of all count-models. It is further noteworthy that "oil and fat" PDOs' presence (zero-model) was negatively related to landscapes characterized by structural change (C2), although with a significant difference between non-Mediterranean (b* = −1.06) and Mediterranean (b* = −0.20) regions.

Geographically weighted regression

In addition to the purely mathematical regression model presented above, we calculated a geographically weighted regression model based on the spatial dataset of the PDOs and the component scores for each NUTS-3 region. The local coefficient of determination R^2 (quality-of-fit) revealed a clear gradient running from southwestern Europe with the highest quality-of-fit (R2 = 0.7) to north-eastern Europe with R^2 as low as 0.1. It revealed above-average R^2-values mainly for the Mediterranean countries plus Ireland and the southwest UK. As expected, the models' estimations for PDO presence, worked better in regions with more PDOs, thus having more data points to calculate the regression model. From the same GIS tool, we retrieved a locally calculated standard deviation, explaining where the observed number of PDOs differed from what the local regression model would suggest (Figure 5). Overall, the regions with more PDOs than suggested by the regression model turned out to be congruent with the European hotspots of PDO production and thus, proving the basic concept of the current model. However, the deviation patterns for particular product types may indicate an unused potential for PDO production but might also point toward missing model parameters. In total, there are many more regions where PDO production is strongly underestimated: As shown in Figure 5, dark green areas indicating that the observed values lie two standard deviations above the expected value were more frequent than regions where PDO production was strongly

overestimated (i.e., dark orange areas indicating that the observed values lie two standard deviations below the model's estimation).

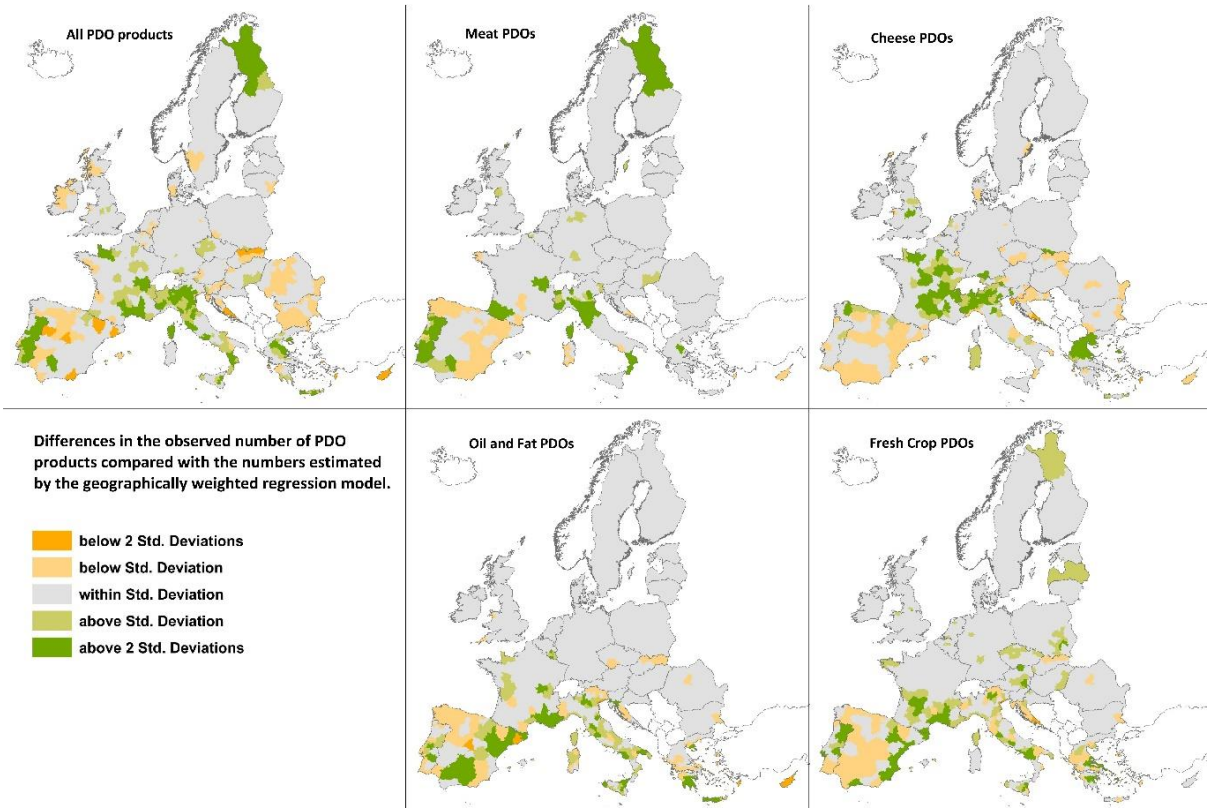

Figure 4.5 Difference between the observed and expected numbers of PDOs according to the geographically weighted regression model. The difference is displayed in terms of standard deviation and differentiated by PDO product types. This visualization shows, that depending on the product type, there are differences, where the regression under- or over-estimates the presence of PDOs.

4.4 Discussion

At first look, the hurdle models revealed three noteworthy patterns regarding the PDO-landscape relationships. First, we found a clear positive relation between high-ecological values (component 1) and an increased number of PDOs. Second, structural change (component 2) had a significantly different influence on PDOs in the Mediterranean and non-Mediterranean countries. While it was associated with an increase in PDO presence in the Mediterranean, structural change was linked to a decrease in PDO presence in non-Mediterranean countries. Third, the presence and numbers of meat PDOs were significantly different between the Mediterranean and non-Mediterranean countries as well. To analyze the regional differences properly, we introduced a covariable "Mediterranean" to account for the dominance of Mediterranean countries in PDO production. From the hurdle model, we used both, the zero-model values (analyzing the PDOs' presence), and the count-models (analyzing all cases with at least one PDO).

Landscape characteristics in relation to PDO food categories

To investigate differences among certain PDO product types (according to product categories of the PDO scheme), we calculated hurdle models for the four most frequent categories (meat, cheese, oils and fats, and fresh crops) against the respective numbers of PDOs. While PDOs in total appeared to benefit most from

high ecological values and measures of conservation, the picture got more differentiated when looking at particular types of PDO food products, thus the interpretation got more nuanced:

(a) Meat PDOs

In contradiction to the overall picture, the occurrence of meat PDOs was positively linked to structural change (C2). At the same time, the occurrence of meat products was slightly positively linked to landscapes of cultural-touristic values (C3). The presence of non-Mediterranean meat PDOs was predicted much better by component one, than for Mediterranean meat PDOs. Further, according to the count-model, meat PDOs were less associated with the high ecological values (C1) than "oil and fat," and "fresh crops" PDOs. These characteristics might imply that meat PDOs have a strong potential to help build up regional landscape marketing and sustain traditional agro-economic activities within a region (Coutinho et al., 2021). Still, systems dominated by meat PDOs could suffer from ecological and socio-economic deficits. Thus, they could be supported, for example through agri-environmental programs, or with rural development strategies specifically in the Mediterranean countries. The negative linkage between the presence of PDO-labeled non-Mediterranean meat and cultural-touristic landscapes (C3) points toward a mismatch between the traditional cultural values of the PDO products and the current landscape management practices. On the contrary, within the Mediterranean region, high cultural values (C3) were a good indicator of the presence of meat PDOs. This link might be explained by the importance that the Mediterranean diet had on landscape management over centuries (Padilla et al., 2012; Petrillo, 2012). Thus, we assume that Mediterranean meat PDOs could be role models for meat production in traditional and social-ecological valuable systems.

(b) Cheese PDOs

Despite cheese being the most frequently used category among PDO labels, our models showed the least explanatory power for cheese PDOs. The only significant coefficients for cheese PDOs told us, that – just as for meat PDOs – Mediterranean cheese PDOs were positively linked to landscapes characterized by structural change (C2). For cheese PDOs, the non-Mediterranean products were even slightly negatively associated with structural change landscapes (C2). Further, cultural-touristic values (C3) had a slightly positive influence on the presence of cheese PDOs. Considering the large total number of cheese PDOs (192 of 638 PDOs), at first view, it seemed surprising that for this particular sub-sample, the models revealed so little significant information. One explanation might be, that within the cheese category, there are a few dominant products with extraordinarily high annual trading volumes (Chever et al., 2012) and large production areas. Thus the real-world influence of cheese PDOs might be dominated by mass-products like Feta, Parmigiano Reggiano, or Comte and therefore we were not able to identify strong linkages of cheese to particular social-ecological landscape characteristics. The top cheese PDO-producing countries are Greece, Italy, and France. The famous PDO-labeled cheese products (such as Feta, Parmigiano Reggiano, or Comte) are produced there and have high trading volumes (e.g., up to 200,000 tons annually for Parmigiano Reggiano). Therefore those products may be closer to industrial goods than landscape products (Chever et al., 2012). Small-scale cheese PDOs, which more often could be related to remote agricultural sites or mountainous areas presumably have little overall influence on landscape management. Also, it appears, that for cheese products it is more common to join a geographic indication label for the pure reason of earning the premium price, to keep existing businesses alive (Lamarque and Lambin, 2015).

(c) Oil and fat PDOs

"Oil and fat" PDOs followed the overall pattern of all PDOs combined as their presence was best explained by high ecological values (C1). Also here, the presence of non-Mediterranean products was strongly negatively linked to structural change (C2). Also, Mediterranean "oil and fat" PDOs were negatively linked

to structural change (C2), but less strongly. This can probably be explained by the dominance of the Mediterranean countries in olive oil production (olive oils being the dominant product within this category). The cultural-touristic values (C3) were not significantly linked to PDO-labeled "oil and fat" products, which is surprising because olive oil products are, besides cheese and meat products, particularly famous for being PDO-labeled. They are heavily used for regional marketing and there have been scientific studies on this topic coining the term "olive oil tourism" (La Millán-Vazquez de Torre et al., 2017; Folgado-Fernández et al., 2019). Therefore, we assume a mismatch between the perceived cultural-touristic value of olive oil production and the real-world impact on touristic attractiveness. There are aesthetically valuable terraced olive landscapes, but the majority of olive production takes place at rather large and uniform plantations. For that reason, we suggest improving the PDO-landscape relationship through programs that counteract the abandonment of remote or less profitable sites. By making the production of real landscape-shaping products profitable, ecological and cultural values can be preserved at the same time (Egea and Pérez y Pérez, 2016).

(d) Fresh crops and vegetable PDOs

The model results for the PDO category "fruit, vegetables and cereals" (fresh crops) were of a singular nature. It appeared that among all product categories "fresh crop" PDOs showed to strongest positive linkage with ecologically valuable landscapes (C1). In this category, no significant difference between Mediterranean and non-Mediterranean cases appeared. We explain those results with the crop-like management of products within this category and with their relatively low tendency to accumulate in hotspots or to form clusters (Figure 5). Nevertheless, having no significant coefficients for components two and three also means that there are no relevant negative associations of "fresh crop" PDOs with structural change (C2), nor with cultural-touristic values (C3). It appears, that "fresh crop" PDOs (compared to other product categories) are highly targeted to landscapes of high ecological values (C1), but randomly distributed with regard to the other two components. To make the value of "fresh crop" PDOs more holistic it seems necessary to improve their role in a cultural-touristic context and to make them more profitable for producers in remote rural regions (i.e., generating income). As PDO-labeled fruits, vegetables, and cereals, in particular, compete with organic-labeled products (Marescotti et al., 2020) it seems sensible to focus on re-valorizing those PDOs as culturally attractive assets. PDO-labeled "fresh crop" products should not try to compete with their mass-produced counterparts. If promoted better, they could be used as high-quality ingredients in local kitchens, and for premium-priced processed food.

PDO hotspots – potentials and challenges

Within the EU, PDO products are much more prevalent in the Mediterranean countries and tend to form particularly pronounced hotspots in certain regions. In this study, we looked for the reasons behind this uneven distribution by analyzing which social-ecological landscape characteristics coincide with the production of PDOs. Besides the findings on product-type-dependent linkages with landscape characteristics, we also wanted to know where PDO products occurred both more or less often than estimated by our regression models. Figure 5 shows which regions in Europe seem to overperform or underperform in terms of PDO production, indicating accentuated distribution patterns for separate categories of PDO products. From this visualization of overperforming and underperforming regions, we draw two messages:

Acting on the PDOs' uneven distribution in Europe

Overall, the models revealed a relatively clear and uniform picture. Being in a Mediterranean region, had the largest positive effect on the presence of PDOs, and ecologically valuable landscapes were positively linked to PDO production. On the contrary, landscapes characterized by structural change were, overall, negatively linked to the presence of PDOs. However, when looking at the count models' coefficients for the covariable "Mediterranean" the picture becomes more nuanced: It appears, that the number of meat PDOs is more strongly linked to the Mediterranean region than to any other product category. And while the pure presence of cheese PDOs (zero-model) is best explained by the covariable "Mediterranean," the effect on the number of PDOs (count-model) is the lowest among all categories. Meanwhile, the number of "oil and fat" as well as "fresh crop" PDOs is not significantly influenced by the covariable "Mediterranean." This points toward a highly uneven distribution of PDOs of different categories in Europe. The green and orange clusters in Figure 5 visualize this uneven distribution and display the differences among the four product categories. The observed clusters of overperforming regions might have emerged from traditional landscape management systems or production methods (Bérard and Marchenay, 2006). For example, the areas that overperform in terms of oil and fat PDOs are mostly situated along the Mediterranean coast – hosting the traditional landscapes of olive cultivation. Meanwhile, in northern Europe, PDOs only play a small role in food production. Therefore, we claim that PDOs probably will never be evenly spread across Europe because of regional environmental advantages or historical-traditional differences.

The European Union considers the geographical indications (GI) scheme (including the PDOs), to be a supporting instrument for rural development (European Commission, 2020a). To do so, they not only need to incentivize sustainable practices within the existing production systems, but they also have to promote the geographical indication schemes – especially in the non-Mediterranean regions and markets. For example, we found that our regression model predicted at least some presence of cheese PDOs in southern Denmark (Figure 5). Instead, there are no PDOs registered in Denmark. This, however, cannot be explained by the absence of traditional food culture, but more reasonable with a low relevance of PDOs in the Danish market. Studies in Denmark find a general disinterest in PDOs from consumers and producers (Goudis and Skuras, 2021), and higher market shares of the competing organic products segment (European Commission, 2018, 2019). This example somehow proves the concept and function of the geographically weighted regression model: Because given the frequent milk production in southern Denmark and the existence of well-known Danish PGI cheese products (e.g., Esrom or Danbo cheese), it appears realistic that cheese PDOs could emerge from those landscapes. However, having the positive relationships between PDO production and landscape management in mind, rural regions could profit from strengthening the existing PDO products' situation or adopting the PDO label for existing traditional products (Escribano et al., 2020).

Using plant-based PDOs' for improving sustainability

Different sub-regions of the overall PDO hotspots are specialized in certain product types. For example, in France, northern Italy, and northern Greece, we found green clusters of overperforming areas in terms of cheese PDO production. Specifically for cheese, most of the produced volume appears to concentrate on very few high-turnover products related to industrial and intensive production systems. Meanwhile, overperforming areas of oil and fat PDOs, as well as fresh crops PDOs, are spread more widely. Given the surplus of "overperforming" regions, we assume that some of the PDO hotspot areas may operate close to their productive potential, which seems obvious given the limited spatial extent of any PDO (Vandecandelaere et al., 2018). This potential limitation might only be a product-specific limit within a certain region. For example, regions overperforming in terms of meat PDOs (such as central Portugal) might have additional potential for fresh crops PDOs. For incentivizing the registration of new PDO-labeled products, it appears sensible to focus on the plant-based categories, such as "oil and fat" or "fruits,

vegetables, and cereals" (fresh crops), when transitioning toward multifunctional landscapes. So far, plant-based products were less attractive for being registered as PDOs because they are often sold as raw products or in a less processed form with lower added values. This could be improved by supporting plant-based products in general, or more specifically by indicating and promoting the use of raw PDO products in further processed foodstuffs. Finally, more high-quality plant-based products are necessary to transform diets and agricultural production toward more healthy and sustainable systems (Röös et al., 2017; Willett et al., 2019; Gerten et al., 2020).

Limitations and outlook

Although the selection of variables was meant to be comprehensive in a social-ecological sense, we cannot claim that the 12 initially selected variables fully represent the landscapes or regional systems, nor can they reflect all aspects of sustainability. That is because from the beginning our selection of variables was meant to specifically reflect social-ecological aspects of geographically protected food products and their respective landscapes of origin. Anyhow, for our aim to explore the relations between landscapes and products, the models worked well. The regression models' quality-of-fit was rather satisfying for such complex systems that we tried to model. We retrieved several significant regression coefficients and thereby were able to reveal tendencies that were plausible within the bigger picture.

For further research, we see two interesting pathways to follow. On one hand, it will be insightful to investigate the current Mediterranean PDO hotspots in-depth and to gain empirical field data about the landscape-product relationship, probably measured in terms of ecosystem services (Ghazoul et al., 2009; Belletti et al., 2015; Lamarque and Lambin, 2015). Regarding the existing PDOs, it appears necessary to analyze the current level of their sustainability and how sustainability efforts can be institutionalized within the European GI scheme (Kizos et al., 2017). So far, the amendments (i.e., updates) to PDO regulations submitted by the producer groups do not focus on environmental issues often but are mostly made to improve the economic situation (Quiñones-Ruiz et al., 2018). We recommend initiating a step-by-step transition of the PDO certification toward a sustainability label.

On the other hand, it would be helpful to better understand the reasons for the uneven distribution within Europe, exploring the influence of food cultural heritage and underlying social-ecological landscape characteristics. Also understanding the social and political circumstances under which PDOs are developed and registered seems crucial (Quiñones-Ruiz et al., 2016). To promote PDOs in Northern Europe as a means of sustainable landscape management they need to target suitable landscapes. Thus, the explanatory models for PDO distribution need to be improved to identify high-potential landscapes for PDO production. A relevant overlapping with the HNVF concept seems reasonable but has to be investigated at a local scale. Given their unclear interaction with demographic and cultural aspects, we further recommend focusing research more on plant-based PDO products. While we acknowledge that PDO products cannot be "invented" from scratch but need a foundation in local food traditions and management practices, they should be adapted to changing market situations (Gugerell et al., 2017).

Preserving the 'geographical origin' idea

Relating to current policies, we want to highlight that the Farm to Fork strategy of the European Commission sets out to transform the European agricultural system into a sustainable food system and one explicit part of this strategy is the utilization of Geographical Indications (European Commission, 2020a). However, the specific meaning of that sustainability goal is not well-defined (Schebesta and Candel, 2020). As the PDOs' current legal definitions focus on regionality, food traditions, and landscape practices, those rules inherently – but not explicitly – incorporate notions of sustainable and ecologically sound production

(Belletti et al., 2015; Egea and Pérez y Pérez, 2016). In this sense, PDOs represent a substantial and yet unused potential to contribute to the implementation of the European Green Deal with its Farm to Fork and biodiversity strategies. To keep up with this aspirational goal, it needs a science-based approach to analyze and monitor the sustainability efforts within PDO production. Otherwise, the PDO scheme faces the risk of a market-oriented commodification of its products (Quiñones-Ruiz et al., 2018; Marescotti et al., 2020).

While we assumed for large parts of this article that most PDO products are landscape-related and come from less intensive systems than their non-labeled counterparts, that is not true for every single registered product (Cozzi et al., 2019). Also concerning socio-economic sustainability indicators (e.g., generational renewal, or food transport miles) PDOs do not always perform better than comparable non-labeled products (Ferrer-Pérez and Gil, 2019). There is evidence that some existing products are not perfectly in line with the central idea of the basic PDO concept, either given their economic turnover, geographical extent, or lack of a landscape-quality relationship. For example, in Italy, more than 80% of the annual turnover of GI products is achieved by only 10 brands (Higgins, 2018). Further, there is a Czech spice "Ceský kmín" that can be produced in the whole country, and Feta cheese reaches an annual export volume of 400 million Euros, accounting for the majority of the turnover of all Greek GI products (European Commission, 2020b). Under this impression, we recommend a sustainability-oriented fitness check of the PDOs. This fitness check should refine the current requirements for labels, maybe adding sustainability criteria to the PDO legislation, and re-checking the eligibility and credibility of existing PDO products' landscape aspects.

4.5 Conclusion

With this study, we were able to highlight and differentiate the potential of PDOs to support sustainable landscape management. We found that PDOs appear to be a particularly suitable food labeling strategy in landscapes of high ecological values and landscapes with a strong representation of conservation areas. This confirms our first assumption that high environmental values favor the production of PDOs. Especially plant-based PDOs seem to interact positively with ecological valuable landscapes. Structural change is only clearly linked to the Mediterranean meat and cheese PDOs. Thus, our second assumption only holds true for this sub-sample. For plant-based PDO products, we did not observe this effect. Lastly, we consider our third assumption as proven, with two specifications added: We argue that Mediterranean PDO products are particularly good entry points to combine the ecological and socio-economic aspects of sustainable landscape management. Whereas for non-Mediterranean PDOs mainly the cultural links should be strengthened. Although the trends for different product categories were diverse, we argue that PDOs should be seen as helpful tools for holistic rural development policies.

Our findings underline the potential of the geographical indications scheme for implementing the Farm to Fork strategy and the European Green Deal. We could show that landscapes hosting PDO-labeled products can also contribute to the sustainable development agenda, without however claiming a direct causal linkage. To overcome this uncertainty, an additional sustainability "add-on regulation" for PDOs (for example PDO+) could guarantee that sustainability safeguards are met. To be labeled PDO+, a production system would need to meet a list of criteria specifying both sustainable management practices and landscape characteristics. The resulting sustainable PDOs could be promoted as a tool for implementing the Farm to Fork strategy and introduce an additional consumer preference for high-value products. As many landscapes that yield PDO-labeled products are already managed using sustainable practices, additional costs to farmers and administration could be kept low. Additionally, supporting policies (e.g., provided by the CAP) could particularly support these certified areas or exclude them from the "conditionality" for direct payments.

Meanwhile, socio-economic sustainability aspects are not yet addressed by this certification scheme. However, in regions with little to no registered products, PDO labeling can offer additional income opportunities in rural areas, allowing less intensive production methods to stay economically viable, and allowing management of cultural landscapes to become profitable for current and future generations. Given the strong existing relationship between PDOs and ecologically valuable landscapes, these labels have a high potential for producing synergies across different sustainability dimensions including nature conservation, cultural values, regional identities, and rural income.

References Chapter 4

Andersson E, Nykvist B, Malinga R, Jaramillo F, Lindborg R (2015) A social-ecological analysis of ecosystem services in two different farming systems. Ambio 44 Suppl 1: S102-12. 10.1007/s13280-014-0603-y

Belletti G, Marescotti A, Sanz-Cañada J, Vakoufaris H (2015) Linking protection of geographical indications to the environment: Evidence from the European Union olive-oil sector. Land Use Policy 48: 94–106. 10.1016/j.landusepol.2015.05.003

Bérard L, Marchenay P (2006) Local products and geographical indications: taking account of local knowledge and biodiversity. Int Social Science J 58 (187): 109–116. 10.1111/j.1468-2451.2006.00592.x

Cameron AC, Trivedi PK (2013) Regression Analysis of Count Data., Second Edition. Cambridge University Press. Cambridge. 10.1002/sim.768

Chever T, Renault C, Renault S, Romieu V (2012) Value of production of agricultural products and foodstuffs, wines, aromatised wines and spirits protected by a geographical indication (GI). Final Report. Brussels

Clark LF, Kerr WA (2017) Climate change and terroir: The challenge of adapting geographical indications. J World Intellect Prop 20 (3-4): 88–102. 10.1111/jwip.12078

Coutinho P, Simões M, Pereira C, Paiva T (2021) Sustainable Local Exploitation and Innovation on Meat Products Based on the Autochthonous Bovine Breed Jarmelista. Sustainability 13 (5): 2515. 10.3390/su13052515

Cozzi E, Donati M, Mancini MC, Guareschi M, Veneziani M (2019) PDO Parmigiano Reggiano Cheese in Italy. In: Arfini F, Bellassen V (eds) Sustainability of European Food Quality Schemes. Multi-Performance, Structure, and Governance of PDO, PGI, and Organic Agri-Food Systems. Springer International Publishing, Cham, pp 427–449. 10.1007/978-3-030-27508-2_22

Egea P, Pérez y Pérez L (2016) Sustainability and multifunctionality of protected designations of origin of olive oil in Spain. Land Use Policy 58: 264–275. 10.1016/j.landusepol.2016.07.017

Escribano M, Gaspar P, Mesias FJ (2020) Creating market opportunities in rural areas through the development of a brand that conveys sustainable and environmental values. Journal of Rural Studies 75: 206–215. 10.1016/j.jrurstud.2020.02.002

European Commission (2018) Europeans, Agriculture and the CAP. Brussels

European Commission (2019) Organic farming in the EU. A fast growing sector. Brussels

European Commission (2020a) Farm to Fork Strategy - For a fair, healthy and environmentally-friendly food system. Brussels

European Commission (2020b) Study on economic value of EU quality schemes, geographical indications (GIs) and traditional specialities guaranteed (TSGs). Final Report. Brussels. 10.2762/396490

European Council (1992) Council Regulation (EEC) No 2081/92. of 14 July 1992 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. Brussels

European Council (2012) Regulation (EU) No 1151/2012 of the European Parliament and of the Council of 21 November 2012 on quality schemes for agricultural products and foodstuffs. L 343. Brussels

Ferrer-Pérez H, Gil JM (2019) PGI Ternasco de Aragón Lamb in Spain. In: Arfini F, Bellassen V (eds) Sustainability of European Food Quality Schemes. Multi-Performance, Structure, and Governance of PDO, PGI, and Organic Agri-Food Systems. Springer International Publishing, Cham, pp 355–376. 10.1007/978-3-030-27508-2_19

Flinzberger L, Zinngrebe Y, Plieninger T (2020) Labeling in Mediterranean agroforestry landscapes: a Delphi study on relevant sustainability indicators. Sustainability Sci. 15 (5): 1369–1382. 10.1007/s11625-020-00800-2

Folgado-Fernández JA, Campón-Cerro AM, Hernández-Mogollón JM (2019) Potential of olive oil tourism in promoting local quality food products: A case study of the region of Extremadura, Spain. Heliyon 5 (10): e02653. 10.1016/j.heliyon.2019.e02653

Fournier L-S, Michel K (2017) Mediterranean Food as Cultural Property? Towards an Anthropology of Geographical Indications. In: May S, Sidali KL, Spiller A, Tschofen B (eds) Taste | Power | Tradition. Göttingen University Press, Göttingen. 10.17875/gup2017-1004

Gerten D, Heck V, Jägermeyr J, Bodirsky BL, Fetzer I, Jalava M, Kummu M, Lucht W, Rockström J, Schaphoff S, Schellnhuber HJ (2020) Feeding ten billion people is possible within four terrestrial planetary boundaries. Nat. Sustainability 495: 305. 10.1038/s41893-019-0465-1

Ghazoul J, Garcia C, Kushalappa C (2011) Landscape Labeling approaches to PES: Bundling Services, Products and Stewards. In: Ottaviani D, Scialabba NE-H (eds) Payments for Ecosystem Services and Food Security, Rome, pp 171–204

Ghazoul J, Garcia C, Kushalappa CG (2009) Landscape labeling: A concept for next-generation payment for ecosystem service schemes. For. Ecol. Manage. 258 (9): 1889–1895. 10.1016/j.foreco.2009.01.038

Goudis A, Skuras D (2021) Consumers' awareness of the EU's protected designations of origin logo. Br. Food J. 123 (13): 1–18. 10.1108/BFJ-02-2020-0156

Gugerell K, Uchiyama Y, Kieninger PR, Penker M, Kajima S, Kohsaka R (2017) Do historical production practices and culinary heritages really matter? Food with protected geographical indications in Japan and Austria. Journal of Ethnic Foods 4 (2): 118–125. 10.1016/j.jef.2017.05.001

Higgins DM (2018) Brands, Geographical Origin, and the Global Economy. Cambridge University Press. 10.1017/9781139507059

Jackman S (2020) pscl: Classes and Methods for R Developed in the Political Science Computational Laboratory. R package version 1.5.5. United States Studies Centre, University of Sydney, Sydney, New South Wales, Australia

Kizos T, Koshaka R, Penker M, Piatti C, Vogl CR, Uchiyama Y (2017) The governance of geographical indications. Br. Food J. 119 (12): 2863–2879. 10.1108/BFJ-01-2017-0037

Kizos T, Vakoufaris H (2009) Alternative Agri-Food Geographies? Geographic Indications in Greece. Tijdschrift voor economische en sociale geografie 102 (2): 220–235. 10.1111/j.1467-9663.2010.00612.x

La Millán-Vazquez de Torre MG, Arjona-Fuentes JM, Amador-Hidalgo L (2017) Olive oil tourism: Promoting rural development in Andalusia (Spain). Tourism Management Perspectives 21: 100–108. 10.1016/j.tmp.2016.12.003

Lamarque P, Lambin EF (2015) The effectiveness of marked-based instruments to foster the conservation of extensive land use: The case of Geographical Indications in the French Alps. Land Use Policy 42: 706–717. 10.1016/j.landusepol.2014.10.009

Mann C, Plieninger T (2017) The potential of landscape labeling approaches for integrated landscape management in Europe. Landscape Res. 42 (8): 904–920. 10.1080/01426397.2017.1335863

Marescotti A, Quiñones-Ruiz XF, Edelmann H, Belletti G, Broscha K, Altenbuchner C, Penker M, Scaramuzzi S (2020) Are Protected Geographical Indications Evolving Due to Environmentally Related Justifications? An Analysis of Amendments in the Fruit and Vegetable Sector in the European Union. Sustainability 12 (9): 3571. 10.3390/su12093571

May S (2016) Ausgezeichnet! - Zur Konstituierung kulturellen Eigentums durch geografische Herkunftsangaben. Universitätsverlag Göttingen

Mullahy J (1986) Specification and testing of some modified count data models. Journal of Econometrics 33 (3): 341–365. 10.1016/0304-4076(86)90002-3

Nagelkerke NJD (1991) A note on a general definition of the coefficient of determination. Biometrika 78 (3): 691–692. 10.1093/biomet/78.3.691

Oteros-Rozas E, Ruiz-Almeida A, Aguado M, González JA, Rivera-Ferre MG (2019) A social-ecological analysis of the global agrifood system. PNAS. 10.1073/pnas.1912710116

Padilla M, Capone R, Palma G (2012) Sustainability of the foodchain from field to plate: The vase of the Mediterranean diet. In: Burlingame BA, Dernini S (eds) Sustainable diets and biodiversity. Directions and solutions for policy, research and action. FAO, Rome, pp 230–240

Pe'er G, Bonn A, Bruelheide H, Dieker P, Eisenhauer N, Feindt PH, Hagedorn G, Hansjürgens B, Herzon I, Lomba Â, Marquard E, Moreira F, Nitsch H, Oppermann R, Perino A, Röder N, Schleyer C, Schindler S, Wolf C, Zinngrebe Y, Lakner S (2020) Action needed for the EU Common Agricultural Policy to address sustainability challenges. People Nat. 10.1002/pan3.10080

Petrillo PL (2012) Biocultural Diversity and the Mediterranean Diet. In: Burlingame BA, Dernini S (eds) Sustainable diets and biodiversity. Directions and solutions for policy, research and action. FAO, Rome, pp 222–229

Quiñones-Ruiz XF, Forster H, Penker M, Belletti G, Marescotti A, Scaramuzzi S, Broscha K, Braito M, Altenbuchner C (2018) How are food Geographical Indications evolving? – An analysis of EU GI amendments. Br. Food J. 120 (8): 1876–1887. 10.1108/BFJ-02-2018-0087

Quiñones-Ruiz XF, Penker M, Belletti G, Marescotti A, Scaramuzzi S, Barzini E, Pircher M, Leitgeb F, Samper-Gartner LF (2016) Insights into the black box of collective efforts for the registration of Geographical Indications. Land Use Policy 57: 103–116. 10.1016/j.landusepol.2016.05.021

R Core Development Team (2020) R Project

Röös E, Bajželj B, Smith P, Patel M, Little D, Garnett T (2017) Protein futures for Western Europe: potential land use and climate impacts in 2050. Reg. Environ. Change 17 (2): 367–377. 10.1007/s10113-016-1013-4

Schebesta H, Candel JJL (2020) Game-changing potential of the EU's Farm to Fork Strategy. Nat. Food 1 (10): 586–588. 10.1038/s43016-020-00166-9

Tashiro A, Uchiyama Y, Kohsaka R (2019) Impact of Geographical Indication schemes on traditional knowledge in changing agricultural landscapes: An empirical analysis from Japan. Journal of Rural Studies 68: 46–53. 10.1016/j.jrurstud.2019.03.014

Török Á, Moir HVJ (2018) The market size for GI food products – evidence from the empirical economic literature. Stud. Agr. Econ. 120 (3): 134–142. 10.7896/j.1816

Vakoufaris H, Belletti G, Kizos T, Marescotti A (2014) Protected Geographical Indications and the landscape: towards a conceptual framework. Meeting of the Workshops for the implementation of the European Landscape Convention: 'Sustainable Landscapes and Economy: on the inestimable natural and human value of the landscape'. Unpublished. Urgup

Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, Garnett T, Tilman D, DeClerck F, Wood A, Jonell M, Clark M, Gordon LJ, Fanzo J, Hawkes C, Zurayk R, Rivera JA, Vries W de, **Majele Sibanda L, Afshin A, Chaudhary A, Herrero M, Agustina R, Branca F, Lartey A, Fan S, Crona B, Fox E, Bignet V, Troell M, Lindahl T, Singh S, Cornell SE, Srinath Reddy K, Narain S, Nishtar S, Murray CJL** (2019) Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet 393 (10170): 447–492. 10.1016/S0140-6736(18)31788-4

Zeileis A, Kleiber C, Jackman S (2008) Regression Models for Count Data in R. J. Stat. Soft. 27 (8). 10.18637/jss.v027.i08

Chapter 5
Landscape management in PDO production systems

Original title: Is the 'Protected Designation of Origin' an indicator for sustainable landscape management? Insights from pasture-based animal husbandry in five EU countries. *by Flinzberger L, Plieninger T, Bugalho MN, and Zinngrebe Y (2023) preprint of unpublished manuscript: resolver.sub.uni-goettingen.de/purl?gro-2/138994*

Abstract

Previous research has shown that products labeled as 'Protected Designation of Origin' (PDO) correlate positively with indicators for landscape sustainability. However, specific factors that turn PDO products into sustainable landscape management tools remain vague. We analyze interviews from six European production systems to explore the links between PDO-labeled products and sustainable landscape management. All case studies were linked to extensive and pasture-based animal husbandry. We found that PDO products can contribute to sustainable landscape management if income is supplemented by well-adapted incentives for agri-environmental measures. Successful products are further associated with local networks that use synergies between different stakeholder interests. By introducing eligibility criteria that focus on the various social-ecological goals, PDO labeling could become a sustainability standard. Due to their social-ecological influence at the landscape level, PDO products can be a powerful addition to the EU's Green Deal and rural development strategy.

5.1 Introduction

Sustainable landscape management as a paradigm for European agricultural landscapes

Current agricultural intensification in Europe tends to result in monotonous landscapes with reduced cultural values (Tieskens et al., 2017; van Vliet et al., 2015) and lower biodiversity (Bouwma et al., 2019; Mupepele et al., 2021). The European Union's agriculture is aligned with the Common Agricultural Policy (CAP) of the European Union. Despite various reforms for "greening" the CAP, this extensive set of schemes and rules remains mostly oriented toward an efficient and market-oriented production of food, feed, and biofuels (Pe'er et al., 2019) without fulfilling its environmental goals (Pe'er et al., 2020). The European Commission launched the 'European Green Deal' (European Commission, 2019), which includes the 'Farm to Fork' strategy, aiming to unify the goals of economically viable and ecologically sound agriculture while ensuring a positive development of rural regions (Schebesta & Candel, 2020). Those goals can be pursued in an integrated way by following the concept of 'sustainable landscape management' (SLM), also known as 'integrated landscape management'. Following this concept entails the simultaneous management of food and fiber production, as well as the conservation of biodiversity and other ecosystem services, while fostering human well-being (Plieninger et al., 2020). Researchers have described SLM as a useful concept for achieving sustainable development goals, covering a broad range from ecological sound practices to improved rural livelihoods (Angelstam et al., 2019; Bürgi et al., 2017). A remarkably comprehensive set of principles for SLM was proposed by Scherr et al. (2015). According to them, sustainable/integrated landscape management is defined by 1) agreement among stakeholders on multiple landscape objectives, 2) shared management of synergies and trade-offs among different landscape uses, 3) management practices that contribute to multiple landscape objectives, 4) supportive markets, policies, as well as incentives, and 5) collaborative decision-making for and through the stakeholders. In this paper, we used these five principles to evaluate the potential of PDO-producing systems to be a key instrument for SLM.

However, sustainability on the landscape level is not well-defined within the CAP and its subordinated sustainability strategies like 'Farm to Fork'. We need, therefore, a better understanding of the practical issues that farmers, landscape managers, and other stakeholders experience when trying to implement or maintain the principles of SLM. In the context of SLM, the agriculturally productive landscape can be seen as a management unit that comprises many aspects of sustainability, and as a spatial level where challenges can be addressed in an integrated way (Tanentzap et al., 2015). Bringing together production and conservation aims (O'Farrell & Anderson, 2010) makes the SLM concept especially useful for a specific type of agricultural product – the landscape product. It appears sensible to focus on landscape products in this study, as their multifunctional characteristics can be seen as best practice cases for SLM. Landscape products are defined by their distinct geographic origin, low-input management in combination with traditional practices, and their perception as high-quality products leading to high revenues (García-Martín et al., 2022). This study thus addresses the lack of knowledge that presently exists on the potential benefits of geographically distinct products to landscape sustainability.

Geographical Indications as instruments for sustainable landscape management

Implementing SLM requires different instruments, policies, and multi-stakeholder governance. A recent instrument that aims to transform European agriculture, considered in the 'Farm to Fork' strategy, is Geographical Indication (GI) labeling (European Commission, 2020). Geographical Indications like the 'Protected Designation of Origin' (PDO) can be seen as prime examples of landscape products. The GI label aims to combine traditional production techniques, unique landscape resources, and high-quality products (Filippo Arfini, 2019). Overall, products labeled as GI have been shown to positively correlate with several social-ecological indicators (Milano & Cazella, 2021). Among the GI labels, the PDO label is the strongest certification that protects agricultural products according to their geographic origin, including their names as intellectual properties. Previous studies have related PDO products to successful agro-ecological practices (Belletti et al., 2015; Owen et al., 2020), or tested specific indicators for their correlation with the numbers of PDO products in a given region (Flinzberger, Zinngrebe et al., 2022). Among those social-ecological indicators was the amount of semi-natural or extensively managed agricultural lands (e.g., agroforestry systems, high nature value farmland), or cultural values based on world heritage sites and tourism indicators (Flinzberger, Zinngrebe et al., 2022). In another study, Flinzberger, Cebrián-Piqueras et al. (2022) revealed connections between PDO products and certain rural landscape typologies in Europe, showing that agricultural landscapes of high environmental value correlate with PDO products across Europe, while the correlation of PDO products and issues of structural change was predominantly found in the Mediterranean region.

For PDO-labeled products (hereafter 'PDO products') their whole production process (including growing feed, processing, and packaging), has to take place within the designated geographical region (Belletti & Marescotti, 2011; European Council, 1992). Understanding PDO products as products directly linked to a certain landscape (Brock, 2023; García-Martín et al., 2021), implies recognizing that their production interacts with the social-ecological trends of that geographical area (Allen & Prosperi, 2016; Vakoufaris et al., 2014). That includes considering environmental and biodiversity aspects, traditions, food culture, local identity, rural development, and tourism (Cei et al., 2021; Lamine et al., 2019). This means that the influence of PDO products reaches beyond productivity and economic aspects, into the arena of landscape governance. The market success of products with an especially regional reputation is influenced by the social-ecological values transmitted through the product and by the marketing (F. Arfini et al., 2011; Barjolle & Sylvander, 1999). Those values are particularly deeply embedded into the product by its place and culture of origin (Filippo Arfini et al., 2019; Raimondi et al., 2018). The statistical and generalizing nature of previous approaches and reviews, however, did not allow the conclusion of direct causal relationships. In this context, PDO products' potential to promote rural development, counteract rural exodus, and contribute to local

livelihoods, as proposed by Dal Ferro and Borin (2017), is worth investigating through a case-based qualitative approach.

Identifying options for developing PDO products through landscape governance

Considering the plurality of stakeholder interests linked to sustainable landscapes, there is a need to analyze synergies and potential trade-offs in specific case-study analyses. In this study, we wanted to uncover how various stakeholders of landscape management (i.e., producers, conservationists, administration, and regional marketing) attribute certain principles of sustainable landscape management to the current production practices of PDO-labeled products. Additionally, we tried to distill the articulated needs of stakeholders for maintaining or implementing those principles within their PDO production systems. By including different types of stakeholders in PDO value chains, we cover multiple perceptions of sustainable landscape management. We selected case studies related to the production of animal-based products, namely cheese and meat, as these are the most relevant product categories of the EU's geographical indications scheme in terms of registered products and achieved revenues. The selected PDO products are all linked to landscapes whose management includes extensive grazing systems or the use of animals for pasture management. To gain insights into stakeholders' perceptions of the links between sustainable landscape management and PDO production, we designed our interviews to answer the following research questions:

1. Which characteristics of PDO-producing systems contribute to sustainable landscape management?
2. Which framework conditions enable stakeholders of PDO-producing systems to harness this potential?

Whereas the results section is structured according to the identified phenomena, the research questions are addressed in the discussion, where we reflect on the current state of PDO production and the potential role of PDO products in future support schemes for sustainable landscape management.

5.2 Methods

The study is based on 46 qualitative interviews with stakeholders collected in six different EU regions in Germany, Portugal, Spain, and Greece. The interviews were carried out between December 2021 and May 2022. To account for the dependencies between different sustainability aspects, we picked a method that focuses on structural overlaps in the interview material. The 'Phenomenon-Centered Text Analysis' (PTA) developed by Krikser and Jahnke (2021), which was also used previously in other fields of science (Wagemann et al., 2022), allowed for a focused interpretation of the overlapping content from single categories (codes).

Selecting cases and interview partners

We selected a subset of similar PDO cases that were comparable in terms of landscape management while representing variations of food cultures across different EU regions. We excluded 'Protected Geographic Indication' (PGI) products because this label only requires one production step to be carried out within the respective region and thus can be less influential on landscape management. The selected study sites shared two main features: a) PDO-producing systems with animal husbandry in extensive grazing systems, and b) farmlands that can be considered as high nature value farmlands because these correlated particularly well with the production of PDO-labeled foods (Flinzberger, Zinngrebe et al., 2022). Further, we focused on animal-based products (meat and cheese) because some of the most iconic landscapes in Europe are managed with the help of grazing and herding. The cases were situated in the heathlands and bog landscapes

of northern Germany, in alpine pasture landscapes of southern Germany, in the Mediterranean oak woodlands of Spain and Portugal, in the semi-mountainous areas of central Greece, and on the Greek island of Limnos (illustrated in Fig. 1). The production systems include cow, sheep, and goat cheeses, as well as beef, ham, lamb, and goat meat (Table 1). For each of the six production systems with a distinctive landscape, we interviewed a minimum of five PDO actors to represent a diversity among relevant stakeholder groups: PDO-registering organizations, local producers, processing or marketing companies, tourism agencies, and landscape management or conservation experts.

Table 5.1 Study regions, their geography, and the included PDO products in these regions

Country & region		Geography and landscape characteristics	Product names	Product type
GER	Allgäu region	- pre-alpine pastures in Bavaria and Baden-Württemberg - temperate conditions with high summer precipitation - pastures used for grazing / meadows for feed production - maintenance of open meadows for milk production	**Allgäuer Emmentaler / Allgäuer Bergkäse**	cow cheese (hard)
	Lüneburger Heide / Diepholzer Moor	- flat heath and peatland pastures under Atlantic climate - shrub vegetation on partly drained peatlands - level of vegetation maintained by grazing sheep - little economic income from meat products	**Lüneburger Heidschnucke**	sheep meat
			Diepholzer Moorschnucke	sheep meat
GR	Elassona municipality	- mountainous plains in hot conditions - close to Olympus national parc - sheep and goat grazing mountainous shrubs - altitudes from 250 – 2,500 m.a.s.l.	**Arnaki Elassonas**	sheep meat
			Katsikaki Elassonas	goat meat
	Lemnos Island	- small island in the northern Aegen Sea (Greece) - rocky and hilly shrublands in hot-dry conditions - sheep and goats utilizing herbs otherwise considered useless shrubs	**Kalathaki Limnou**	sheep cheese (soft)
			Melihloro Limnou	goat cheese (semi-hard)
PT	Alentejo	- hilly cork oak woodlands in central Portugal - climatic region of Mediterranean-Atlantic influence with extremely hot and dry summers - iconic cork oak forests mixed with shrub vegetation - most remote and least inhabited region of Portugal	**Carne Alentejana**	beef
			Presunto do Alentejo	ham
			Queijo de Évora	sheep cheese (hard)
ES	Extremadura (Badajoz and Cáceres provinces)	- hilly to semi-mountainous area in western Spain - partly arid conditions under Mediterranean climate - iconic cork oak forest mixed with shrub vegetation - bird protection areas	**Torta del Casar**	sheep cheese (soft)
			Queso Ibores	goat cheese (hard)
			Dehesa de Extremadura	ham

For each of the six production systems with a distinctive landscape, we interviewed a minimum of five PDO actors to represent different stakeholder groups: PDO-registering organizations, local producers, processing or marketing companies, tourism agencies, and landscape management or conservation experts. Depending on regional peculiarities, there were slight differences in the roles or functions of persons representing a certain stakeholder group. For example, representatives of regional brand initiatives such as "Allgäu GmbH" in Germany, or "Alimentos de Extremadura" in Spain were added as interview guests. In Germany, we included representatives of land care units as stakeholders in landscape management, while in Spain, Portugal, and Greece the relevant conservation experts were found among researchers or environmentally educated staff of administrations.

Figure 5.1 Typical views on extensively managed landscapes from our six case study regions. a) Cattle in Ribatejo region, Portugal (photo by Conceição Caldeira); b) Terraced fields mixed with oak trees in Extremadura, Spain; c) Sheep in the heath meadows around Lüneburg, Germany (photo by Willow on Wikimedia Commons [CC-BY 2.5]); d) Semi-mountainous pastures in the Lemnos region close to Mt. Olympus national park, Greece (photo by Vasileios Deligiannis); e) Meagre pastures with goats on Lemnos island, Greece (photo by Danae Sfakianou); f) Cattle in touristically used alpine pastures in Allgäu region, Germany (photo by Marlene Haiberger on Unsplash).

Interviews, transcriptions, and coding

The interviews were conducted as semi-structured interviews, using guiding questions to stimulate the narrative process. The interview guideline is available within the supplementary material (Annex 1). Two open-ended questions at the beginning asked what the interviewees associated with the landscapes. The second interview section focused on relations between the PDO product and landscape management practices, as well as cultural and economic trends within the region. In the final interview section, respondents could talk about political, cultural, and economic framework conditions that support or hinder PDO systems' success and their ideas on how to make PDO products a more successful instrument for sustainable landscape management. Because of the semi-structured style of the interviews, the context of answers was comparable enough to use a statement-oriented transcription, noting key statements and relevant information during the interviews, and refining it based on the audio recordings afterward (Clausen, 2012). The refined transcriptions were translated into English before being processed with MAXQDA software (VERBI – Software, 2010).

While coding the raw interview material, we assigned separate codes to all emerging aspects of sustainable landscape management under the PDO regime. Landscape management practices as well as management outcomes were both considered, accompanied by remarks on the landscape-product relationships, and statements about current and potential PDO policies. In the first step of structural reduction, codes referring to landscape management were grouped into nine coding categories (Table 2). This simplification was done because the phenomenon-centered text analysis (PTA) method required more generalized coding categories. Those nine codes (listed under 'Social-ecological aspects' in Table 2) were used for the PTA as described below. Text segments coded with 'Associations' and 'PDO-plus' were analyzed separately, without being part of the PTA, yielding background information on the cases.

Table 5.2 Codes used for structuring the interview material with a detailed description of each code.

Code	Code description
Social-ecological aspects	
1) Animal welfare	Remarks on animal welfare practices related to traditional methods and consumer demands
2) Culture	Local identity, traditions, and regionality regarding production, diets, customs, etc.
3) Diversification	Economic diversification on farm level and regional level, including tourism and gastronomic tourism
4) Environment	Environmental issues, ecological sustainability, biodiversity, climate change aspects, and resourcefulness.
5) Governance	Policies related to labeling or agriculture in general, incl. subsidies/incentives, and administration of label
6) Income	Individual and regional income; economic viability of the business models, including remarks on value chains
7) Landscape	Landscape maintenance and practices that link animals with the landscape and its aesthetics
8) Legacy	Generational renewal and quality of rural life connected to maintaining the legacy of the product
9) Quality	Remarks covering taste, healthiness, nutrients, purity, etc. of the product
Associations	Professional relations and personal associations with products, regarding the social-ecological context
PDO-plus	Sentiment towards theoretical PDO+ label, combining regionality and sustainability through specific criteria

Phenomenon-centered text analysis

Combining aspects of quantitative and qualitative text analysis, the phenomenon-centered text analysis (PTA) helped us to uncover six social-ecological phenomena within the interview material by pointing out connections between single coding categories. Based on the transcribed and translated interview material we assigned codes to each text segment like for any common qualitative text analysis. We continued with a content analysis for each code separately (Annex 2), which later helped with the qualitative descriptions of how the codes are linked within the phenomena. Using the MAXQDA code-matrix browser, we calculated the number of text segments per code and per interview within each stakeholder group (Annex 3.1 and 3.2). We found that the different codes appeared relatively even throughout all actors and regions. The only major differences occurred for the 'Animal welfare' code which was often used in the interviews from Allgäu and barely used in the interviews from Extremadura, and the 'Quality' coding, which was used relatively often in the context of Extremadura, but barely in the interviews from Lower-Saxony.

The PTA method follows the assumption that codes that frequently appear in proximity also share a common underlying concept or cause and form a contextual phenomenon. We defined proximity as interview segments overlapping or lying directly next to each other. Subsequently, we counted the overlaps, using the MAXQDA code-relations browser with the 'near' function enabled and the maximum distance set to zero (VERBI, 2020). According to Krikser and Jahnke (2021), we considered all relations between codes as relevant which counted more than half of the maximum overlaps. In our case, the maximum number of overlaps was 38 and thus all relations with 19 or more overlaps were considered. In total we identified six relationships between codes, the so-called 'phenomena'. The codes 'Animal welfare' and 'Quality' were not related to any phenomenon. The final step of the PTA was an in-depth qualitative analysis of every text segment related to a phenomenon to describe how the overlapping aspects interact on a landscape scale. The description of these so-called phenomena is also called 'micro-theories' (Krikser & Jahnke, 2021). The codes for 'Landscape' and 'Income' were most prevalent within the different phenomena and thus, they are discussed as cross-sectoral aspects.

5.3 Results

The following section shows how different aspects of sustainable landscape management are related to each other within the PDO-producing systems. The six phenomena (identified through the PTA method) each represent one set of overlapping sustainability aspects (Table 3). Each phenomenon is summarized and illustrated with direct quotes from the interviews. Based on those findings, commonalities and variations across different product types and case study regions regarding PDO implementation are highlighted. A full list of quotes (including additional quotes and extended statements) is available in the supplementary material, as are the summaries of the phenomenon-unrelated codes 'Animal welfare' and 'Quality' (Annex 4). The quotes are numbered sequentially in their order of appearance, including the quotes from the annex.

Table 5.3 Result from the 'Code-Relations-Browser' from MAXQDA showing the number of overlapping and nearby coded text segments among the nine codes used for the PTA. All codes that have equal to or more than half of the maximum overlaps (38) are emphasized by bold-italic numbers. In the lower half, the six identified phenomena are listed with the number of overlaps given in brackets.

	1)	2)	3)	4)	5)	6)	7)	8)	9)
1) Animal welfare		3	1	6	1	5	3	0	5
2) Culture			10	16	12	***20***	18	8	17
3) Diversification				18	7	14	***23***	4	5
4) Environment					***19***	16	***38***	***26***	10
5) Governance						***28***	15	***23***	12
6) Income	maximum overlaps = 38						***19***	18	11
7) Landscape	relevant overlaps ≥ 38/2 ≥ 19							18	14
8) Legacy									5
9) Quality									

Phenomenon 1 – Landscape-Environment (***38***)
Phenomenon 2 – Landscape-Income (***19***)
Phenomenon 3 – Landscape-Diversification (***23***)
Phenomenon 4 – Environment-Governance-Legacy (***26; 23; 19***)
Phenomenon 5 – Income-Governance (***28***)
Phenomenon 6 – Income-Culture (***20***)

Social-ecological phenomena of PDO production

P1 – Landscape-Environment: PDO production landscapes support biodiversity and ecosystem services

In all regions, the presence of livestock and traditional farming practices were perceived as a crucial element for maintaining landscape aesthetics with fewer trees (e.g., Dehesa or Montado) or no trees at all (e.g., heath- or peatlands). Producers or breeders insisted on the grazing animals as the keepers of the landscape aesthetics and stressed the animals' suitability for grazing on less-productive or difficult-to-farm land. This comes along with high biodiversity values, such as habitats for threatened bird species, that were maintained through grazing or herding and complemented by diverse structures like trees, shrubs, or ponds:

> Q1: *"The land […] is only suitable for grazing […] and the 'Heidschnucke' [local sheep breed] is especially suitable for transferring nutrients from the heathland to the pastures. It is a totally extensive form of grazing, where no fertilization is used. […] many flowers and plants, birds, and reptiles live here – that means high biodiversity."* (R9: producer from Lower Saxony)

There was a major difference between milk and meat production in Extremadura. While grazing sheep and goats, which are kept mainly for milk production, contribute to maintaining the open landscapes, pigs raised

for ham production almost entirely forage on acorns. In this case, the maintenance of the open landscape with holm oak forests must be supported by manual labor. That also means that large parts of the iconic mosaic-like agroforestry systems in the Spanish Dehesa and the Portuguese Montado need human maintenance:

> Q2: *"The Dehesa is not a natural landscape; it is human-made. Instead of having a closed canopy, the open landscape supports a strong ecological diversity"* (R22: conservation expert from Extremadura)

This mix of grazing animals and human maintenance also helps to mitigate large wildfires, which is perceived as a key benefit of those open landscapes that would be lost in case of abandonment. At the same time, PDO-producing landscapes were described as threatened by more profitable and water-intensive crops such as vegetables or pineapples. Statements about the competition for land and water also highlighted the environmental harm that these intensive systems can inflict.

> Q3: *"The cork oak forest [montado] does not need to be watered, the montado lives well with the climatic conditions that exist and feeds that ecosystem without any disruption. These new agricultural practices that threaten the montado are highly predatory of the water resource."* (R45: tourism representative from Alentejo).

Similarly, the Greek producers from Elassona stressed the importance of keeping the landscape and its bio-physical resources intact to maintain the current system and keep the PDO certification.

P2 – Landscape-Income: Market incentives and support measures can strengthen sustainable landscape management in PDO production systems

Landscape management practices across the case study regions, such as breeding and raising grazing livestock, have a common goal: to generate income. This happens through selling products, receiving financial support, or payment for ecosystem services (i.e., rewarding land managers for the conservation of biodiversity). We found regional differences regarding the main motives for landscape management depending on the dominant type of income. In regions with economically successful PDO products, such as Allgäu or Extremadura, landscape management was more production-oriented while still relying on traditional farming systems. In cases where more of the income came from financial support measures or nature conservation funds, such as in the peat and heath landscapes of northern Germany ('Lüneburger Heide' and 'Diepholzer Moor'), landscape management decisions were guided by nature protection goals. Economically barely viable value chains led to a high degree of dependency on financial support or contractual nature conservation:

> Q8: *"One would have to communicate that sheep have a high value for landscape maintenance, […] It needs higher prices but you do something good for climate and biodiversity. […] but in the background the land care association sponsors it."* (R10: conservation expert from Lower Saxony)

While most respondents highlighted the importance of financial support for the maintenance of PDO-producing landscapes, the suggestions were quite different. Wherever the products were sold along relatively stable value chains (e.g., Extremadura, or Allgäu), the respondents demanded support through product marketing or agriculture policies.

> Q9: *"What we do should work in the long term, and for this, there must be a certain economic viability. This includes subsidies and support measures of the agricultural policy, but also income from the products is central. Production is only sustainable over time if there is profitability through production"* (R1: conservationist from Allgaeu)

In regions where the PDO products were less profitable (e.g., 'Diepholz Moorschnucke' or 'Kalathaki Limnou'), respondents asked for more direct forms of income support to improve local livelihoods and sustainable landscape management practices:

> Q10: *"Support for the regional economy is needed very much. The island has a very large percentage of people engaged in animal husbandry and agriculture in general, so products like the Kalathaki help the economy a lot."* (R36: producer on Lemnos)

P3 – Landscape-Diversification: Traditional landscapes are central to tourism activities

The landscape-diversification phenomenon represents the specific relationship between landscape and tourism because tourism was the single most important aspect of economic diversification and thus regional income in all our study regions. This includes the coexistence of different services that landscapes offer. Respondents mentioned for example landscape as aesthetic spaces, wildlife experience, tranquility, and possibilities for recreation as important factors for tourism:

> Q12: *"The extensive areas further away from the farms represent the Allgäu in terms of tourism and aesthetics. There are those beautiful alpine areas below the tree line with open meadows that blossom so beautifully."* (R1: conservation expert from Allgäu).

Many primary producers were too occupied with agricultural work to add diversification to their portfolio. Logically, regions with an integrated landscape-tourism strategy and active governance bodies did much better in this relationship. Especially the Allgäu and Extremadura regions developed regional brands entailing environmental tourism, and gastronomic specialties:

> Q13: *"In Extremadura, there are many shops geared towards tourism. We sell our cheese there. […] Tourists come from Madrid at Easter and buy local products in the shops that they can't buy in a large supermarket. Here they come to eat more traditional and organic products."* (R19: producer from Extremadura)

In the north German study area, the extensively managed landscape attracts recreational tourism as well, but the productive aspect of the PDO was rather small. In this context, we found the statement that 'sustainability' should not be used for tourism marketing. The Spanish 'regulatory councils', which were considered very supportive regarding advertising the PDO products as landscape products, mainly focus on products as regional and gastronomic specialties and not so much on the sustainability aspect too. Although the income from tourism seemed almost unrelated to the PDO production itself, it heavily depends on landscapes, culture, and gastronomy in all investigated regions:

> Q14: *"As a hotel professional with restaurants […], our relation with kalathaki [local cheese] has absolute relevance because we believe that […] the local product should be supported. Regionality in general, as a basis for promotion and the touristic development on the island, has an absolute relation to the primary sector."* (R34: Tourism stakeholder from Lemnos)

P4 – Environment-Governance-Legacy: Framework conditions for continued PDO existence

According to our respondents, governance plays an important role in both protecting environmental values, and the future of the products, hence the legacy of traditional production and landscapes. Overall, it was stated that more support from the CAP would be necessary to keep up traditional production and that the CAP payments should be more targeted towards provisioning and cultural services. Especially in the case

of PDO products with a lower production volume, supportive instruments and a better integration of environmental and agricultural regulations were demanded to keep the systems alive:

> Q18: *"Depending on the leasing contract, different agri-environmental measures are counted as double subsidies. Those who don't know correctly make contracts that are unfavorable for shepherds."* (R10: conservation expert from Lower Saxony)

Regarding the governance aspect of their products' legacy, many respondents reported about problematic regulations for livestock production and demanded financial incentives for adopting innovations. In parallel, provisioning ecosystem services (provision of hay, grass, acorns, etc.) was called crucial for the continued existence and ensuring certain quality traits of the products:

> Q19: *"Having animals grazing directly in natural pastures and sown pastures in well-managed cork oak forest improves the milk quality for cheese production."* (R42: producer from Alentejo)

Respondents also referred to cultural ecosystem services, in the form of recreational areas, touristic attractiveness, and aesthetic values. They stressed that cultural services have their foundations in the historically grown landscape management practices, such as herding, grazing, or mountain agriculture:

> Q20: *"People want to buy immersive experiences in nature, that are harmless to nature, they want to fully enjoy it, they want to take with them the products that the cork oak forest (montado) produces."* (R45: tourism representative from Alentejo)

P5 – Income-Governance: A high demand for political and financial support

Respondents stated that political and financial support measures are necessary to keep up traditional production. They demanded that politics should do more to generate or stimulate income from PDO products. From the producers' views in particular, the CAP should provide more support for low-intensity and less profitable animal systems. Further, they demanded reduced administrative efforts and streamlined conservation regulations with agricultural support policies, as illustrated by a response from Germany:

> Q24: *"Lower Saxony guideline demands annual grazing, which then qualifies for grazing premium. Nature conservation administration demands however three times grazing per year. […] there are contradictions between nature conservation administration and commercial management."* (R13: producer from Lower Saxony)

Many respondents demanded more targeted payments for the ecosystem services they produce or deliver to the public. Respondents from northern Germany in particular demanded long-term commitments regarding land access rights for maintaining livestock systems without economic risks. Further, respondents expressed the need for administrations to bear additional management expenses, for example, costs stemming from new food safety regulations, or costs for offsetting damages done by wolves:

> Q25: *"Five years is a short period [for contractual nature conservation] and a loss of the funding afterwards would threaten the existence of shepherds. Longer funding periods would be needed for such livestock projects."* (R11: producer from Lower Saxony)

Also, regional administrations could support the producers by bearing the costs of centralized marketing efforts. In general, Mediterranean products appeared to be better represented by centralized PDO administration. Interviewees in Extremadura stressed that the economic success of their products is largely based on network structures that connect different PDO products as well as gastronomy and tourism:

Q26: *"The offices promoting the labels and certified products do an incredible job. We are doing just fine in this regard. […] Political investments into structures and marketing are essential to maintain the production system."* (R25: producer from Extremadura)

Other governance measures can have positive effects on rural livelihoods, for example by offering and maintaining affordable infrastructure (e.g., internet, commuting). In the remote areas of Extremadura and Elassona, this was seen as important as income to counteract rural exodus.

P6 – Income-Culture: Traditions around food culture and management practices make PDO production financially viable

This phenomenon highlights the fact that income for rural communities was connected to the traditional management practices and the resulting products by many respondents. Whether the food culture or the food-related income evolved first, was seen differently among the respondents. They however agreed, that maintaining the traditional low-intensity management practices would be necessary to maintain the uniqueness of the PDO-landscapes, but also that despite traditional aspects, they need to adapt to modern requirements of food production:

Q30: *The breeder is a Businessman, […] so the first thing we need to see is whether traditional techniques can be financially viable. Also, […] traditional techniques must keep pace with modern food hygiene requirements.* (R37: conservationist from Lemnos)

While local identity was an aspect related to PDO production everywhere, gastronomy was more important in the Mediterranean countries. The gastronomy-related aspects help to turn PDO-labeled products into flagships which leads to higher incomes from traditionally produced food. Thus, the stakeholders of the PDO value chain saw themselves as guardians of local heritage:

Q31: *"The name of the ham is directed towards marketing – an egoistic motivation – because certification makes the production more visible. […] It creates a joint image of local identity, traditional landscapes, biodiversity, and local resources."* (R14: producer from Elassona)

In turn, the traditional management practices were culturally more important in Germany, where the income from landscape tourism is just as important, or even more important than the income from agricultural production.

Q32: *"Allgäu lives from tourism, cheese dairies live from tourism […] tourism needs the traditional production process and the cheese dairies need tourism."* (R8: producer from Allgäu)

5.4 Discussion

This study investigated stakeholders' perceptions of the relationship between PDO-labeled products and sustainable landscape management (SLM) using case studies from six pasture systems in the EU. We found that from stakeholders' perspectives, the success and persistence of PDO-labeled products is largely influenced by two factors: landscape maintenance, and income opportunities. Five of the six identified phenomena included either the code 'Landscape' or the code 'Income'. We claim that phenomenon two (landscape-income) touches all of the SLM principles proposed by Scherr et al. (2015), at least indirectly, but looking at the other five phenomena as well provides a more detailed picture. By indicating their numbers, we refer to relevant quotes from the interviews of which some are placed in Annex 4. Drawing on the principles of SLM, we propose three central findings:

1) The commercialization of PDO-labeled products puts stakeholders in a position to maintain landscape management practices that contribute to several landscape objectives at once (**SLM principles one and three**), such as biodiversity conservation (Q2; Q6), cultural values (Q31; Q32), touristic attractiveness (Q13 - Q15), and maintenance of aesthetically beautiful landscapes (Q4; Q12). Looking into the phenomena that include landscape management, environmental benefits, and the legacy of PDO production, it becomes clear that the current state of PDO management already fulfills the SLM principles one and three, obviously with minor regional differences.

2) The interviews revealed that central marketing agencies or network hubs enable a more integrated approach to landscape management (**SLM principles two and five**). This was prominently displayed in the cases of Extremadura and Allgaeu, where centralized marketing makes traditional landscape management economically more viable through diversification (Q14; Q26). The regional differences regarding successful collaborative management are described in the phenomena that feature culture, diversification, and governance.

3) Stakeholders from all case study areas criticized the poorly adapted policies and support measures (**SLM principle four**) which often are not suitable for multifunctional livestock systems (Q18; Q22; Q28), do not reward landscape management that produces multiple benefits (Q8; Q9; Q29) or collide with rules of nature conservation (Q24; Q25). Because income is related to policies in many ways, stakeholders have strong opinions and demands but only little control over the issues described in the governance-income phenomenon.

Which characteristics of PDO-producing systems contribute to sustainable landscape management?

We found that key stakeholders of PDO production relate environmental (Q1; Q5) and cultural values (Q33) to sustainable landscape management. Aspects such as biodiversity conservation (Q2; Q6) and reduced wildfire risk (Silva et al., 2020), or the maintenance of aesthetic landscape fostering touristic attractiveness (La Millán-Vazquez de Torre et al., 2017) were linked to the traditional (Q12) and less-intensive practices (Q11) which are promoted and supported by the PDO label. Those benefits were assigned to low-input management practices like herding, grazing, and grassland production, which in turn led to mosaic-like, multifunctional landscapes. Structurally rich landscapes are often perceived as aesthetically valuable (Q4), where both domesticated animals and wildlife may contribute to economic diversification (Q3), mainly through tourism (Batista et al., 2017; Folgado-Fernández et al., 2019). Working towards multiple objectives at the same time, as observed in the case study areas, aligns with **SLM principle number three**. Although sustainable landscape management is the reason for the inherent sustainability of many agricultural systems from which PDO products emerge, also PDO production can be intensified to a point where overgrazing leads to a loss of traditional landscape elements.

In our case study regions, we found two main ways of generating income from landscape management. There was income generation from the landscape product itself, making the characteristic landscape a production factor and using it as a marketing instrument (Q13). Farmers involved in related activities can be seen as part-time landscape conservationists. On the other hand, income can also be sourced from tourism (Q15; Q16) or environmental protection funds (Q9). For example, the well-maintained heathland areas around Lüneburg (northern Germany) are used as recreational sites and promoted as tourism destinations, while at the same time, herders can receive money for contractual nature conservation (Q18). The Portuguese "goats as firefighters" program is another neat example of compensating land managers for their provision of public services like fire prevention. In the landscapes related to our case studies, livestock turned out to be a powerful tool to combine sustainable landscape management and a continuous and sustainable stream of income. In accordance with **SLM principle number one**, stakeholders must agree on the multiple objectives of landscape management.

We found evidence that local networks for geographically protected products are key for supporting the products and integrating them into regional brand strategies, which is in line with the more theoretical work of Jansujwicz et al. (2021). The uptake of sustainable landscape management approaches works best when various actors collaboratively decide on management practices, value chains, and regulations (Zinngrebe et al. 2020), thus combining **SLM principles number one and three**. As observed particularly in Extremadura and Allgäu, centralized marketing and brand building for the entire region helps to integrate these functions and thus appears to be more promising than promoting single products (Q26). In general, the marketing for PDO products from the Mediterranean region seems to focus a little more on the socio-economic outcomes than the environmental ones, which is also supported by other studies (Cozzi et al., 2019; Ferrer-Pérez & Gil, 2019).

Which framework conditions enable stakeholders of PDO-producing systems to harness this potential?

Understanding PDO products as landscape products and acknowledging their importance within these complex systems makes them a key element for sustainable landscape management (Turner et al., 2020). By the nature of their environmental and socio-economic embeddedness, they can help to close the gap between food as a commodity and landscape management for social-ecological conservation and human well-being (García-Martín et al., 2022). While some PDO products are economically very successful, most PDO-related agricultural systems are characterized by low-input management which mostly is a trade-off for income unless there is a compensation scheme (e.g., agro-environmental subsidies). In the case of subsidies or economic incentives for PDO production, which were demanded by many respondents (Q27 – Q29), governance bodies should ensure that those are not environmentally harmful as underlined by **SLM principle number two**. Because environmental policies require baselines and indicators (Asioli et al., 2020; Borrello et al., 2022) the sustainability of PDO products would benefit from clear environmental standards in this sense.

Another enabling condition we identified was a well-adapted incentive system. Because landscape management is always a question of economics (Plieninger et al., 2015) the producers among our interviewees saw financial support measures as a natural part of their cash flow. They were aware of the additional ecosystem services, which they are maintaining through their landscape management (Q2; Q5), and logically, they want to get compensated for their service to society (Peterson et al., 2014), which is also in line with **SLM principle number four**. Among our respondents, we found the common perception that CAP payments are too focused on intensive monoculture (Q3) systems. They claimed that the CAP payments do not reward the multiple societal values and environmental outputs that stem from PDO-related agricultural systems (Q28). The stakeholders' statements align with research findings indicating that, despite expressing support for sustainability and multifunctionality, a significant portion of the CAP funds are still

allocated to payments rooted in the productivist discourse (Erjavec & Erjavec, 2015). Instead, CAP funds should be redirected toward management approaches that deliver multiple benefits at once through conserving multifunctional landscapes, including the biodiversity values and ecosystem services they provide.

Economic diversification in the investigated PDO-producing landscapes almost exclusively focused on tourism, which was managed in a particularly professional manner by networking agencies. For example, achieving touristic attractiveness based on a certain landscape is almost impossible for a single producer (Q16). It needs coordinated efforts by several institutions (Q13; Q26), which was also found in other studies (Parga-Dans et al., 2020; Tieskens et al., 2017) and is reflected in **SLM principle number five**. In the case study regions, we identified local networks and regional marketing agencies as useful actors and entry points for supportive measures. Promoting PDO products as a part of the landscape identity and cultural heritage paves the way for future strategies to support rural development in those landscapes.

5.5 Conclusion

PDO products are catalysts for a positive social-ecological development of rural areas, but they can rarely initiate or drive a positive trend on their own. Stakeholders of PDO production reported that PDO-labeled products are the main reasons for the continuation of extensive management in traditional landscapes and thereby help to generate various social-ecological benefits. The success and persistence of PDO products, however, are tightly linked to several framework conditions. Among those necessary conditions are successful regional marketing and brand-building, integration with tourism, maintenance of regional value chains, the attractiveness of rural areas and related professions, as well as targeted support measures for all those elements. However, it needs further investigation of how landscape connectedness and regional characteristics of value chains influence the values attached to the PDO products, also for other categories than milk or meat products.

We conclude that wherever PDO products should continue to exist, the income either must come from a certain food culture (e.g., Torta del Casar) or the attractiveness of sustainably managed landscapes (e.g., Diepholzer Moorschnucke). In the best case, both are combined in a balanced way (e.g., Allgäu cheese, Dehesa de Extremadura, or Lemnos cheese). From the interviews, we learned, that this combination of having a successful food product but also a diversified income through nature tourism, is best reached by local or regional marketing networks. Both, traditional landscape management and regional food culture seem to play a crucial role in the success of PDO marketing. While food culture is easier to communicate to distant places, the value of sustainable landscape management can almost only be perceived within the PDO products' regions. From this finding, we distinguish two major development strategies for different types of PDO products, both of which can support the underlying sustainable landscape management:

i) PDO products with a unique and well-known food heritage can better transmit social-ecological values through the product itself. Thus, they are better suited for reaching a wider audience and serving geographically distant markets. It must be ensured that marketing success does not undermine environmental integrity.

ii) PDO products that draw their main value from representing a unique and iconic form of landscape management may be better marketed within the region. They probably can draw more benefits from any kind of nature-based tourism integrated with the gastronomic experience, and from being paid for environmental services or nature protection.

For both options, supportive governance should try to stimulate PDO-producing systems in two ways. On the one hand, through offering incentives or financial support as a reward for providing ecosystem services

to the public. On the other hand, governance can support PDO production through beneficial regulations and cultural valorization of the products. To ensure context-sensitive implementation, those measures appear to be better administered on a regional or local level while responding and reporting to national and European targets. Above all, the support measure should be aligned along the key principles of sustainable landscape management with its multiple environmental and cultural objectives. While the cultural aspect is already part of the PDO legislation regarding production and landscape management, the environmental aspect could be added by introducing basic sustainability standards to the label. Those could be voluntary first, and later become mandatory, or be the starting point for a sustainable regionality label. By doing so, the agenda to use the Geographical Indications scheme for a sustainable transformation of Europe's agriculture – following the 'Farm to Fork' strategy – could be brought forward substantially.

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Ethical statement: We enabled the recipients to participate by informed consent in the following way: (i) During the introduction, we described the objectives of the interview and clarified that the survey is part of a research project. (ii) We pointed out that participation in the interview is voluntary and that the analysis will be conducted anonymously. (iii) We left contact information to address any arising questions or concerns of the participants.

Data availability: The interview guideline, the summarized interview results, the coding frequencies needed for the phenomenon-centered text analysis, and direct quotes from the interviews that illustrate the topic will be made available via the publisher's platform once the manuscript is published as a peer-reviewed article.

References Chapter 5

Allen T, Prosperi P (2016) Modeling Sustainable Food Systems. Environmental management 57 (5): 956–975. 10.1007/s00267-016-0664-8

Angelstam P, Munoz-Rojas J, Pinto-Correia T (2019) Landscape concepts and approaches foster learning about ecosystem services. Landscape Ecol 34 (7): 1445–1460. 10.1007/s10980-019-00866-z

Arfini F (2019) EU Food Quality Policy: Geographical Indications. In: Dries L, Heijman W, Jongeneel R, Purnhagen K, Wesseler J (eds) EU Bioeconomy Economics and Policies: Volume 2. Palgrave Macmillan, Cham, pp 27–46. 10.1007/978-3-030-28642-2_3

Arfini F, Albisu LM, Giacomini C (2011) Current situation and potential development of geographical indications in Europe. In: Sylvander B, Barham E (eds) Labels of origin for food. Local development, global recognition. CABI, Cambridge, pp 29–44. 10.1079/9781845933524.0029

Arfini F, Antonioli F, Donati M, Gorton M, Mancini MC, Tocco B, Veneziani M (2019) Conceptual Framework. In: Arfini F, Bellassen V (eds) Sustainability of European Food Quality Schemes. Multi-Performance, Structure, and Governance of PDO, PGI, and Organic Agri-Food Systems. Springer International Publishing, Cham, pp 3–21. 10.1007/978-3-030-27508-2_1

Asioli D, Aschemann-Witzel J, Nayga RM (2020) Sustainability-Related Food Labels. Annu. Rev. Resour. Econ. 12 (1): 171–185. 10.1146/annurev-resource-100518-094103

Barjolle D, Sylvander B (1999) Some factors of success for origin labelled products in agri-food supply chains in Europe: market, internal resources and institutions. Le Mans. 10.22004/AG.ECON.241033

Batista T, Mascarenhas JM de, **Mendes P** (2017) Montado's ecosystem functions and services: the case study of Alentejo Central – Portugal. The Problems of Landscape Ecology XLIV: 15–27

Belletti G, Marescotti A (2011) Origin Products, Geographical Indications and Rural Development. In: Sylvander B, Barham E (eds) Labels of origin for food. Local development, global recognition. CABI, Cambridge, pp 75–91

Belletti G, Marescotti A, Sanz-Cañada J, Vakoufaris H (2015) Linking protection of geographical indications to the environment: Evidence from the European Union olive-oil sector. Land Use Policy 48: 94–106. 10.1016/j.landusepol.2015.05.003

Borrello M, Cecchini L, Vecchio R, Caracciolo F, Cembalo L, Torquati B (2022) Agricultural landscape certification as a market-driven tool to reward the provisioning of cultural ecosystem services. Ecological Economics 193: 107286. 10.1016/j.ecolecon.2021.107286

Bouwma I, Zinngrebe Y, Runhaar H (2019) Nature Conservation and Agriculture: Two EU Policy Domains That Finally Meet? In: Dries L, Heijman W, Jongeneel R, Purnhagen K, Wesseler J (eds) EU Bioeconomy Economics and Policies: Volume 2, vol 56. Palgrave Macmillan, Cham, pp 153–175. 10.1007/978-3-030-28642-2_9

Brock S (2023) What is a food system? Exploring enactments of the food system multiple. Agric Hum Values. 10.1007/s10460-023-10457-z

Bürgi M, Ali P, Chowdhury A, Heinimann A, Hett C, Kienast F, Mondal MK, Upreti BR, Verburg PH (2017) Integrated Landscape Approach: Closing the Gap between Theory and Application. Sustainability 9 (8): 1371. 10.3390/su9081371

Cei L, Stefani G, Defrancesco E (2021) How do local factors shape the regional adoption of geographical indications in Europe? Evidences from France, Italy and Spain. Food Policy 105: 102170. 10.1016/j.foodpol.2021.102170

Clausen A (2012) The Individually Focused Interview: Methodological Quality Without Transcription of Audio Recordings. TQR 17: 1–17. 10.46743/2160-3715/2012.1774

Cozzi E, Donati M, Mancini MC, Guareschi M, Veneziani M (2019) PDO Parmigiano Reggiano Cheese in Italy. In: Arfini F, Bellassen V (eds) Sustainability of European Food Quality Schemes. Multi-Performance, Structure, and Governance of PDO, PGI, and Organic Agri-Food Systems. Springer International Publishing, Cham, pp 427–449. 10.1007/978-3-030-27508-2_22

Dal Ferro N, Borin M (2017) Environment, agro-system and quality of food production in Italy. Italian Journal of Agronomy 12 (793): 133–143. 10.4081/ija.2017.793

Erjavec K, Erjavec E (2015) 'Greening the CAP' – Just a fashionable justification? A discourse analysis of the 2014–2020 CAP reform documents. Food Policy 51: 53–62. 10.1016/j.foodpol.2014.12.006

European Commission (2019) A European Green Deal. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en. Accessed 11 Oct 2021

European Commission (2020) A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system. Brussels

European Council (1992) Council Regulation (EEC) No 2081/92. of 14 July 1992 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. Brussels

Ferrer-Pérez H, Gil JM (2019) PGI Ternasco de Aragón Lamb in Spain. In: Arfini F, Bellassen V (eds) Sustainability of European Food Quality Schemes. Multi-Performance, Structure, and Governance of PDO, PGI, and Organic Agri-Food Systems. Springer International Publishing, Cham, pp 355–376. 10.1007/978-3-030-27508-2_19

Flinzberger L, Cebrián-Piqueras MA, Peppler-Lisbach C, Zinngrebe Y (2022a) Why Geographical Indications Can Support Sustainable Development in European Agri-Food Landscapes. Front. Conserv. Sci. 2. 10.3389/fcosc.2021.752377

Flinzberger L, Zinngrebe Y, Bugalho MN, Plieninger T (2022b) EU-wide mapping of 'Protected Designations of Origin' food products (PDOs) reveals correlations with social-ecological landscape values. Agron. Sustain. Dev. 42 (3). 10.1007/s13593-022-00778-4

Folgado-Fernández JA, Campón-Cerro AM, Hernández-Mogollón JM (2019) Potential of olive oil tourism in promoting local quality food products: A case study of the region of Extremadura, Spain. Heliyon 5 (10): e02653. 10.1016/j.heliyon.2019.e02653

García-Martín M, Huntsinger L, Ibarrola-Rivas MJ, Penker M, D'Ambrosio U, Dimopoulos T, Fernández-Giménez ME, Kizos T, Muñoz-Rojas J, Saito O, Zimmerer KS, Abson DJ, Liu J, Quintas-Soriano C, Sørensen IH, Verburg PH, Plieninger T (2022) Landscape products for sustainable agricultural landscapes. Nat Food 3 (10): 814–821. 10.1038/s43016-022-00612-w

García-Martín M, Torralba M, Quintas-Soriano C, Kahl J, Plieninger T (2021) Linking food systems and landscape sustainability in the Mediterranean region. Landscape Ecol. 36 (8): 2259–2275. 10.1007/s10980-020-01168-5

Jansujwicz JS, Calhoun AJK, Bieluch KH, McGreavy B, Silka L, Sponarski C (2021) Localism "Reimagined": Building a Robust Localist Paradigm for Overcoming Emerging Conservation Challenges. Environmental management 67 (1): 91–108. 10.1007/s00267-020-01392-4

Krikser T, Jahnke B (2021) Phenomena-centered Text Analysis (PTA): a new approach to foster the qualitative paradigm in text analysis. Qual Quant. 10.1007/s11135-021-01277-6

La Millán-Vazquez de Torre MG, Arjona-Fuentes JM, Amador-Hidalgo L (2017) Olive oil tourism: Promoting rural development in Andalusia (Spain). Tourism Management Perspectives 21: 100–108. 10.1016/j.tmp.2016.12.003

Lamine C, Garçon L, Brunori G (2019) Territorial agrifood systems: A Franco-Italian contribution to the debates over alternative food networks in rural areas. Journal of Rural Studies 68: 159–170. 10.1016/j.jrurstud.2018.11.007

Milano MZ, Cazella AA (2021) Environmental effects of geographical indications and their influential factors: A review of the empirical evidence. Current Research in Environmental Sustainability 3: 100096. 10.1016/j.crsust.2021.100096

Mupepele A-C, Bruelheide H, Brühl C, Dauber J, Fenske M, Freibauer A, Gerowitt B, Krüß A, Lakner S, Plieninger T, Potthast T, Schlacke S, Seppelt R, Stützel H, Weisser W, Wägele W, Böhning-Gaese K, Klein A-M (2021) Biodiversity in European agricultural landscapes: transformative societal changes needed. Trends in ecology & evolution. 10.1016/j.tree.2021.08.014

O'Farrell PJ, Anderson PML (2010) Sustainable multifunctional landscapes: a review to implementation. Current Opinion in Environmental Sustainability 2 (1-2): 59–65. 10.1016/j.cosust.2010.02.005

Owen L, Udall D, Franklin A, Kneafsey M (2020) Place-Based Pathways to Sustainability: Exploring Alignment between Geographical Indications and the Concept of Agroecology Territories in Wales. Sustainability 12 (12): 4890. 10.3390/su12124890

Parga-Dans E, González PA, Enríquez RO (2020) The social value of heritage: Balancing the promotion-preservation relationship in the Altamira World Heritage Site, Spain. Journal of Destination Marketing & Management 18: 100499. 10.1016/j.jdmm.2020.100499

Pe'er G, Bonn A, Bruelheide H, Dieker P, Eisenhauer N, Feindt PH, Hagedorn G, Hansjürgens B, Herzon I, Lomba Â, Marquard E, Moreira F, Nitsch H, Oppermann R, Perino A, Röder N, Schleyer C, Schindler S, Wolf C, Zinngrebe Y, Lakner S (2020) Action needed for the EU Common Agricultural Policy to address sustainability challenges. People Nat. 10.1002/pan3.10080

Pe'er G, Zinngrebe Y, Moreira F, Sirami C, Schindler S, Müller R, Bontzorlos V, Clough D, Bezák P, Bonn A, Hansjürgens B, Lomba A, Möckel S, Passoni G, Schleyer C, Schmidt J, Lakner S (2019) A greener path for the EU Common Agricultural Policy. Science (New York, N.Y.) 365 (6452): 449–451. 10.1126/science.aax3146

Peterson JM, Caldas MM, Bergtold JS, Sturm BS, Graves RW, Earnhart D, Hanley EA, Brown JC (2014) Economic linkages to changing landscapes. Environmental management 53 (1): 55–66. 10.1007/s00267-013-0116-7

Plieninger T, Kizos T, Bieling C, Le Dû-Blayo L, Budniok M-A, Bürgi M, Crumley CL, Girod G, Howard P, Kolen J, Kuemmerle T, Milcinski G, Palang H, Trommler K, Verburg PH (2015) Exploring ecosystem-change and society through a landscape lens: recent progress in European landscape research. Ecol. Soc. 20 (2). 10.5751/ES-07443-200205

Plieninger T, Muñoz-Rojas J, Buck LE, Scherr SJ (2020) Agroforestry for sustainable landscape management. Sustain Sci 15 (5): 1255–1266. 10.1007/s11625-020-00836-4

Raimondi V, Curzi D, Arfini F, Olper A, Aghabeygi M (2018) Evaluating Socio-Economic Impacts of PDO on Rural Areas. Conegliano. 10.22004/ag.econ.275648

Schebesta H, Candel JJL (2020) Game-changing potential of the EU's Farm to Fork Strategy. Nat. Food 1 (10): 586–588. 10.1038/s43016-020-00166-9

Scherr SJ, Buck L, Willemen L, Milder JC (2015) Ecoagriculture: Integrated Landscape Management for People, Food, and Nature. In: van Alfen NK (ed) Encyclopedia of agriculture and food systems, Second edition. Academic Press, Elsevier Science & Technology; Credo Reference, London, England, Waltham, Massachusetts, Boston, Massachusetts, pp 1–17. 10.1016/B978-0-444-52512-3.00029-2

Silva V, Catry FX, Fernandes PM, Rego FC, Bugalho MN (2020) Trade-offs between fire hazard reduction and conservation in a Natura 2000 shrub–grassland mosaic. Appl. Veg. Sci. 23 (1): 39–52. 10.1111/avsc.12463

Tanentzap AJ, Lamb A, Walker S, Farmer A (2015) Resolving Conflicts between Agriculture and the Natural Environment. PLoS Biol. 13 (9): e1002242. 10.1371/journal.pbio.1002242

Tieskens KF, Schulp CJ, Levers C, Lieskovský J, Kuemmerle T, Plieninger T, Verburg PH (2017) Characterizing European cultural landscapes: Accounting for structure, management intensity and value of agricultural and forest landscapes. Land Use Policy 62: 29–39. 10.1016/j.landusepol.2016.12.001

Turner BL, Meyfroidt P, Kuemmerle T, Müller D, Roy Chowdhury R (2020) Framing the search for a theory of land use. Journal of Land Use Science 15 (4): 489–508. 10.1080/1747423X.2020.1811792

Vakoufaris H, Belletti G, Kizos T, Marescotti A (2014) Protected Geographical Indications and the landscape: towards a conceptual framework. Meeting of the Workshops for the implementation of the European Landscape Convention: 'Sustainable Landscapes and Economy: on the inestimable natural and human value of the landscape'. Unpublished. Urgup

van Vliet J, Groot HL de, **Rietveld P, Verburg PH** (2015) Manifestations and underlying drivers of agricultural land use change in Europe. Landscape Urban Plann. 133: 24–36. 10.1016/j.landurbplan.2014.09.001

VERBI (2020) MAXQDA 2020 Manual. https://www.maxqda.com/help-mx20/welcome

VERBI – Software (2010) MAXQDA. VERBI – Software. Consult. Sozialforschung. GmbH. Berlin

Wagemann J, Tewes C, Raggatz J (2022) Wearing face masks impairs dyadic micro-activities in nonverbal social encounter: A mixed-methods first-person study on the sense of I and Thou. Frontiers in psychology 13: 983652. 10.3389/fpsyg.2022.983652

Chapter 6
Discussing PDO-labeled products as 'flagship products'

The work on this Ph.D. project, over the course of four years, delivered interesting findings and hopefully offers helpful insights into the role of geographically labeled products for sustainable landscape management. This chapter will focus on the role that PDO-labeled products may play within the agenda for more sustainable European agriculture. Therefore, we take into consideration that the consciousness for PDO-labeled products differs heavily throughout Europe and that the economic success of PDO-labeled products can have a huge impact on their relation to landscape management. Depending on the previous two factors, options to further develop the PDO scheme will be discussed as well as alternatives to geographical indications. Based on theory and practice gaps that were identified, it presents policy recommendations as well as future research options.

As indicated by the title of this dissertation, geographic indications in general, and some PDO-labeled products in particular, can be seen as 'flagship products' that make sustainable landscape management more visible. The original concept of 'flagship species' refers to those animal or plant species that are particularly well-known or iconic, and that are often used as symbols to represent the conservation values of a particular region or ecosystem (Verissimo et al. 2011). Flagship species can play important roles in attracting attention to conservation issues and in raising funds for conservation efforts. Most often those 'flagships' represent a blend of socio-economic and conservation goals, for example by increasing the touristic attractiveness of conservation areas (Walpole and Leader-Williams 2002). Similarly, the term 'flagship product' can be used to describe food products that are iconic and represent the cultural, social, and economic values of a particular region or landscape. Another similarity to flagship species is that also for flagship products well-balanced management should incorporate economic and sustainability goals. While currently PDO labels are mainly understood as economic instruments considering cultural values as a vehicle, this thesis also investigates their sustainability potential. Like flagship species, flagship products can play important roles in attracting attention to the conservation values of a particular landscape, for example through promoting culinary-oriented tourism. Therefore, flagship products can be used as powerful tools to promote sustainable landscape management and support the achievement of sustainability goals at the landscape level. For putting the idea of flagship products into practice, the following sections discuss two types of findings: a) A set of necessary framework conditions for PDO-labeled products to become a supportive instrument for sustainable landscape management. b) A consideration of chances and challenges when transforming the PDO label into a sustainability label, based on stakeholder opinions.

Framework conditions for PDO labels as landscape management instruments

Following the arguments presented in chapter five, the maintenance of PDO production can be approached through two strategies accompanied by an appropriate policy mix (Flinzberger et al. 2023 in review). The first strategy is based on marketing and branding. Wherever products, the landscapes behind the products, or both are well known, there is a good chance to receive a sufficient income for agricultural businesses from selling the products as premium foods. In this case, support in the form of landscape-oriented regional branding through tourism agencies or the like is promising to tap into synergies between the food industry, landscape management, and tourism. The second strategy focuses more on the environmental benefits and synergies with nature conservation. In those cases, where PDO products are less profitable themselves, or when they are produced under more economically challenging conditions, the most suitable option seems to support the income through contractual nature conservation. By doing so, the aspect of sustainable landscape management is a more pronounced feature of the product. This way, farmers also become landscape stewards, and their products can be marketed at a more local level as high-quality niche products

(Flinzberger et al. 2023 in review). It is worth mentioning that both strategies are complementary and are not presented as an either-or decision.

Considering the PDO label as a supportive instrument for sustainable landscape management highlights a conflict between the economic success and landscape-connectedness of PDO-labeled products. Although crops, fruits, vegetables, or similar raw agricultural products should be connected to their landscapes of production equally strongly as processed products, it appears that their connection is less suitable for marketing. The categories of cheese and meat products dominate the list of PDO-labeled products not only in terms of registered products but also because the annual turnover is a lot higher for those processed products (European Commission 2020b). This is presumably related to the premium characteristics attached to the more processed products which are particularly stressed in marketing (e.g., extra-long ripening periods, or traditional processing methods). One might argue that reducing the number of processing steps establishes a stronger connection between products and their respective landscapes, but the contrary seems to be true. It is during these processing steps that local agricultural products are transformed into traditional and regional specialties. This contradiction leads to the challenge of how to enhance the prominence of less-processed PDO-labeled products, which are often plant-based products, within the framework of geographical indications. Policy-oriented research with the involvement of value chain stakeholders could help draft sensible pathways for strengthening less-processed products. Against the backdrop of current recommendations for sustainable food systems, strengthening plant-based products offers multiple benefits to ecosystems and people. One idea for that purpose could be an adapted geographical indication label for products that contain PDO-labeled ingredients.

It is apparent from the results presented above that the numbers of PDO-labeled products are unbalanced between the Mediterranean countries and the countries of northeastern Europe. With ongoing research, it became questionable whether this label may mostly be a Mediterranean phenomenon (Flinzberger et al. 2022b). Probably because of the consciousness for their Mediterranean food culture, there was broad political support for registering GI products in the past. To date, there is still an observable difference in institutional support regarding the financing of centralized marketing agencies. The approach to marketing and the willingness to turn regional products into worldwide demanded goods was more pronounced within the Mediterranean PDO sector. However, even within the Mediterranean countries, remarkable hotspots of PDO production can be found, such as the border area between Spain and Portugal, southern France, and northern Italy (Flinzberger et al. 2022b). Also, a landscape classification based on social-ecological indicators, as presented in chapter four (Flinzberger et al. 2022a), suggests that differences cannot be explained solely by institutional efforts. This Ph.D. project was unable to cover aspects around food culture, food traditions, and consumer decisions in depth, but based on field experiences it is likely that Mediterranean food culture could be one key reason for the observed imbalance in PDO distribution between northern and southern Europe.

A strategy to learn from successful PDO brands (e.g., Dehesa de Extremadura, or Allgaeu Cheese) is the formation of cross-platform brands, where food products, landscape tourism, and cultural attractions are commercialized together. Based on observations during the case-study interviews, it appears sensible to incentivize landscape stakeholders to form networks to influence the rural well-being and local economy beyond the pure economic success of the food products. Currently, PDO-labeled products of international character that generate high annual revenues can be found mainly among cheese products such as Comte, Feta, or Parmigiano Reggiano. However, there can be tension between the idea of PDO-labeled products as geographically certified products and the reality that some of them become internationally famous and are exported worldwide. By requiring that PDO-labeled products are produced in a limited geographic area and meet certain production standards, the geographical indications scheme seeks to ensure that these products are unique and distinct and that they reflect the specific characteristics of the region in which they are produced. It is important to recognize that the success of PDO-labeled products on the global market can bring both benefits and challenges. On the one hand, the success of the products can provide economic

opportunities and support the viability of small-scale producers in the region by taking on the role of a flagship product. On the other hand, when trying to maximize the output from a PDO-producing system, it becomes questionable whether the conservation of biodiversity and the protection of bio-cultural resources can be maintained, and whether the regional characteristic can be upheld. The creation of an internationally demanded brand can raise questions about the regional authenticity of the product and if there are still small-scale producers or rather an industrial value chain. Quantitative research of consumer perceptions across Europe could help to elucidate the limits up to which the association of a product with the landscape of origin still works.

Chances and challenges for sustainable PDO certification

The lack of clear environmental standards is a crucial point to be improved if PDO products (or geographical indications in general) are envisioned to be at the forefront of the sustainable transformation of the EU's agricultural policy. While geographical indications can support the preservation of traditional practices and bio-cultural resources, other labeling schemes may be necessary to provide information to consumers that is more precise. By considering the strengths and limitations of different labeling schemes, it is possible to identify the best ways to promote sustainable production and consumption patterns and to support the achievement of overall sustainability goals. To aim for the current policy goals as expressed in the Farm to Fork strategy (European Commission 2020a), it could nevertheless be helpful to introduce more environmental sustainability standards into the geographic labeling scheme. By doing so, geographical indications could become a more comprehensive instrument for sustainable production and consumption. For designing the envisioned standards, the social-ecological indicators that were proven to correlate with the regions of PDO production can be used (Flinzberger et al. 2022b, Flinzberger et al. 2022a). Those standards could, for example, require management plans on how to implement high nature value farming practices, a climate change and adaption strategy, or a strategy on how to keep the added value within the landscape or community. Further, it seems necessary to check existing PDO-labeled products, not only for their compliance with potential sustainability standards but also for their compliance with the original idea of typical regional products with a strong connection to landscape and culture. During interviews, many stakeholders stressed the mutual dependency between landscape management and PDO-labeled products. Based on these insights, it seems obvious that only products from extensively managed landscapes should be eligible to receive a sustainability-oriented PDO label. Assuming, that the numeric imbalance of PDO-labeled products will persist to a certain degree, this would need to be considered when transforming the geographical indications scheme into a labeling standard for social-ecological sustainability. When doing so, the described regional and cultural differences must be considered when designing the potential sustainability standards.

There is a kind of competition between geographical labeling and organic certification, which shows clear parallels to the north-south gradient of the geographical indications scheme. As shown in chapter two, organic certification was praised by experts for its clear design and straightforward standards, while the geographical indications were seen to fit better when promoting extensive landscape management (Flinzberger et al. 2020). There are only a few studies that explicitly address the differences between the organic label and the geographical indications scheme regarding their familiarity among populations. So far, literature shows that from a consumer standpoint, the PDO label is preferred when it comes to quality traits and thus an according willingness to pay, while the organic label is preferred when it comes to health or sustainability aspects (Roselli et al. 2018, Aprile et al. 2012). Further, it appears that higher awareness for geographical indications goes along with lower interest in buying organic products and vice versa. It is, therefore, safe to say that the non-existent production of PDO-labeled products in one country (e.g., Denmark) has negative effects on familiarity with this type of label (Flinzberger et al. 2022b). However, the underlying, historical, or cultural reasons for this difference remain unclear and should be investigated with approaches of consumer and market research. Once there is a better understanding of the cultural relevance

of PDO-labeled products in comparison to other labels, there will be the chance to make the geographic labeling more relevant in the northeastern European countries as well. It is open to future research as well to uncover under which conditions organic certification and geographical labeling can co-exist. Although it appears sensible to add sustainability standards to the geographic indications scheme it should not be transformed into a 'second' organic label. Instead, it should keep its conceptional breadth, including integrated social-ecological standards from the beginning.

After all, high nature value farming (HNV-F), as represented perfectly by agroforestry or similar mosaic-like management systems, seems to be an optimal starting point for certifying food products for sustainability and regionality (Flinzberger et al. 2020). Integrating sustainability standards based on HNV-F characteristics into the geographical indications scheme could transform it into a more comprehensive labeling scheme with sustainable landscape management at its heart. Because it could also increase the complexity and transaction costs of registering geographical indications, the integration of sustainability standards should be carefully designed and consider the needs and concerns of producers and other relevant stakeholders. As chapter three showed, a significant number of PDO-labeled products are already linked to high nature value farming (Flinzberger et al. 2022b). By specifically promoting this connection, it seems possible to synergistically support the conservation of these landscapes and improve the value of agricultural products. Understanding PDO-labeled products as potential flagship products for the conservation of those landscapes seems promising. By doing so, both the integrity of the landscape systems and the reputation of PDO-labeled products could benefit from extensive and sustainable forms of landscape management. Designing the environmental standards based on existing correlations with sustainable landscape management approaches (e.g., HNV-F, or agroforestry) could help to make those standards more accessible to producers and stakeholders.

References Chapter 6

Aprile MC, Caputo V, Nayga Jr RM (2012) Consumers' valuation of food quality labels: the case of the European geographic indication and organic farming labels. International Journal of Consumer Studies 36 (2): 158–165. 10.1111/j.1470-6431.2011.01092.x

European Commission (2020a) A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system. Brussels

European Commission (2020b) Study on economic value of EU quality schemes, geographical indications (GIs) and traditional specialities guaranteed (TSGs). Final Report. Brussels. 10.2762/396490

Flinzberger L, Cebrián-Piqueras MA, Peppler-Lisbach C, Zinngrebe Y (2022a) Why Geographical Indications Can Support Sustainable Development in European Agri-Food Landscapes. Front. Conserv. Sci. 2. 10.3389/fcosc.2021.752377

Flinzberger L, Plieninger T, Bugalho MN, Zinngrebe Y (2023 in review) Is the 'Protected Designation of Origin' an indicator for sustainable landscape management? Insights from pasture-based animal husbandry in five EU countries

Flinzberger L, Zinngrebe Y, Bugalho MN, Plieninger T (2022b) EU-wide mapping of 'Protected Designations of Origin' food products (PDOs) reveals correlations with social-ecological landscape values. Agron. Sustain. Dev. 42 (3). 10.1007/s13593-022-00778-4

Flinzberger L, Zinngrebe Y, Plieninger T (2020) Labeling in Mediterranean agroforestry landscapes: a Delphi study on relevant sustainability indicators. Sustainability Sci. 15 (5): 1369–1382. 10.1007/s11625-020-00800-2

Roselli L, Giannoccaro G, Carlucci D, Gennaro B de (2018) EU quality labels in the Italian olive oil market: How much overlap is there between geographical indication and organic production? Journal of Food Products Marketing 24 (6): 784–801. 10.1080/10454446.2017.1413473

Verissimo D, MacMillan DC, Smith RJ (2011) Toward a systematic approach for identifying conservation flagships. CONSERVATION LETTERS 4 (1): 1–8. 10.1111/j.1755-263X.2010.00151.x

Walpole MJ, Leader-Williams N (2002) Tourism and flagship species in conservation. Biodiversity and Conservation 11 (3): 543–547. 10.1023/A:1014864708777

Chapter 7
Concluding remarks

This Ph.D. thesis has provided valuable insights into the potential of PDO-labeled products as flagship products for sustainable landscape management in European agriculture. The key results can be summarized within three takeaway messages.

The research found that PDO labels, as a form of geographical indication, can represent and promote cultural landscapes associated with traditional production methods. The correlation between PDO-labeled products and social-ecological indicators underlines the mutual benefits between these products, and the enhancement of environmental sustainability, local economies, and cultural heritage.

To turn PDO-labeled products into successful flagship products for sustainable landscape management this thesis identified three essential elements for success: landscape, people, and economics. The landscapes themselves, with their unique characteristics and biodiversity, play a fundamental role in providing the foundation for PDO-labeled products. Thus, they must be maintained in the first place. The involvement and maintenance of local communities and stakeholders are crucial for sustaining traditional practices which are, in turn, crucial for the preservation of those bio-cultural landscape characteristics. Lastly, financial support, in the form of incentives based on appropriate policies, as well as income from the food products themselves is necessary. To facilitate the production, marketing, and promotion of food landscapes, centralized marketing efforts and integrated regional networks are the instruments of choice for boosting the success of PDO brands.

Based on the finding that PDO labels have the potential to contribute significantly to sustainable agriculture and landscape preservation, it is essential to consider the current limitations of the PDO label as a sustainability label. While PDO labels focus on geographic origin and traditional production methods, they do not necessarily incorporate explicit environmental or social sustainability criteria. Therefore, sustainability standards should be carefully integrated into the PDO label to ensure a more comprehensive approach to sustainable production and consumption.

This thesis showed that the positive effects of extensive agricultural practices can be utilized better through geographic labels as they promote desirable social-ecological development pathways. The findings of this thesis highlight the importance of PDO-labeled products as valuable tools for sustainable landscape management in European agriculture. By preserving cultural landscapes, supporting local communities, and promoting environmentally sound practices, PDO labels can contribute to the achievement of broader sustainability goals. This research hopefully can inform the development of more effective policies and strategies for supporting sustainable landscape management in the European Union by transforming the 'Protected Designation of Origin' into a holistic sustainability label with relevance at the landscape level. Keeping the regional and cultural disparities in mind, PDO-labeled products have the potential to become a helpful tool to combine the sustainability goals of European agriculture and landscape management.

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Declaration

I, Lukas Flinzberger, hereby declare that this Ph.D. thesis titled "Geographic Indications as flagship products for sustainable landscape management in the European Union" (examiners: Prof. Tobias Plieninger, Prof. Miguel Bugalho, Prof. Achim Spiller) has not been presented to any other examining body in its present or similar form. I also affirm that I have not applied for a Ph.D. at any other higher school of education.

Furthermore, I declare that this thesis was prepared independently and without any unauthorized aid and that all aid has been appropriately acknowledged.

Göttingen, 13.09.2023
Lukas Flinzberger