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Forest certification and economic insights: a European perspective

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In recent years, there has been an increasing demand for forest certification and certified forest products in Europe. This trend is related to major worldwide challenges, such as the need to decarbonize the economy and mitigate climate change but also social and consumer demands for wider fair trade. However, whether forest certification influences economic valorization in forestry remains a question. The aim of this study is to analyze forest certification levels across Europe and identify potential relationships between the level of certification in forest areas and relevant economic indicators at country level. This study collected openly available data on total and certified forest areas, economic indicators, and environmental indicators for 28 European countries and explored the correlation between certified forest areas and economic performance in the forestry sector. Findings show that forest certification can significantly improve the economic performance of European forests. It has a more pronounced positive effect on economic incomes than on costs' reduction. While certification costs do rise with the extent of forest area, they tend to stabilize at larger scales, suggesting that the certification process is economically sustainable and scale is relevant. Czechia and the Netherlands stand out for having the highest net values added related to forest certification, reflecting an effective economic exploration of forest resources. This study offers new perspectives to natural and social scientists, as well as to industry and policy makers, by proving contextualized data to support decision making. Additionally, it provides hints for further studies and policy guidelines on sustainable development and the impact of forest certification schemes.

KEYWORDS

forest management, sustainability, FSC, PEFC, policy, market share

1 Introduction

Forest represents around 39% of the overall land cover in Europe (FAO, 2020), with a highly variable distribution across the continent (Maesano et al., 2016; Maes et al., 2023). Northern Europe has the largest amount of forest land at 54%, while Central-East and Central-West Europe have the lowest percentages at 27 and 28%.South-East and South-West Europe have varying percentages at 32 and 36%, respectively (FOREST EUROPE, 2020). Overall, Europe has experienced an increase in forest area in the past few decades as the result of additional afforestation programmes and natural regeneration initiatives on less productive lands (Forster et al., 2021; Maesano et al., 2018).

Forests provide a wide range of ecosystem services, such as climate regulation, carbon sequestration, habitats that support biodiversity and hydrological cycle regulation besides being the focus of livelihoods for millions of people worldwide, with important economic outcomes, such as wood production, non-wood forest products, and ecotourism (FAO and

UNEP, 2020; Ontl et al., 2018; Ontl et al., 2020; Silva et al., 2023; Gutiérrez and Lozano, 2022). In Europe, the forest sector contributes for approximately 1% of the overall Gross Domestic Product (GDP) and employs closely to 2.6 million people (Eurostat, 2023). Climate changes, the expansion of the agriculture dedicated areas and the livestock grazing pressure, the intensive exploitation of forests and frequent wildfires have been causing additional damages to forests (Hansen et al., 1979). These major challenges intensify deforestation and forest degradation, significantly decreasing their global regulating role and the potential benefits to humankind, while increasing the unwanted greenhouse gas emissions, loss of biodiversity, and degradation of soil quality (Curtis et al., 1979; Prevedello et al., 2019).

Sustainable forest management and its relationship to most relevant worldwide goals, such as a low-carbon economy, halt the loss of biodiversity and the mitigation of climate change by contributing to climate neutrality, has boosted the growing interest in certified forest-based products (Yamamoto et al., 2014; Liu and Liu, 2023). This has been driven mainly by public policies that promote sustainable procurement practices for enhancing forest ecosystem services and related environmental benefits, along with the increasing need for design and production of renewable biomaterials (Michal et al., 2019a). European forest policies are highly driven by broader regulatory frameworks. One example is the Regulation on land, land use change, and forestry (LULUCF), which establishes criteria for how the land use sector may contribute to the climate goals of the European Union. The LULUCF Regulation, revised in 2023 for the period of 2024–2030, sets new goals to promote more sustainable land management practices and enhancing carbon sequestration of European forests (Ellison et al., 2014; European Commission, 2018). Additionally, the recent implementation of the Nature Restoration Law further emphasizes the commitment of the European Commission to biodiversity conservation and ecosystem restoration (European Commission D-G for E, 2022). In response to those and other regulatory frameworks and related policies and, to the consumer awareness and demand for sustainable products many companies have now adopted sustainable sourcing policies that require them to rethink the whole value chain and products from certified forests (Zubizarreta et al., 2021).

Forest certification was developed as a tool to promote sustainable forest management practices and to reduce the negative impacts of exploiting forests and their ecosystems (Maesano et al., 2018). Historically, forest certification has emerged as an initiative from the private sector to fill the gaps of public policies and as an alternative to state-driven regulation (Cashore et al., 2004). The two main forest certification schemes globally are the Forest Stewardship Council (FSC) and the Programme for the Endorsement of the Forest Certification (PEFC) (Maesano et al., 2018; Yamamoto et al., 2014; Cashore et al., 2004; Wolfslehner et al., 2019). The FSC, established in 1993, was the first certification scheme to set standards for responsible forest management (FSC, 2023). The PEFC provides a framework for forest certification standards (PEFC I, 2014), allowing national structures to develop their own guidelines adjusted to local conditions and priorities. In addition to forest certification, European policies and guidelines like the EU Forest Strategy, which was revised in 2021, have placed a strong emphasis on sustainable forest management (European Commission, 2021). Moreover, an international commitment to sustainability has been established based on the concept that sustainable development represents an urgent need that should be aimed and accomplished by all countries through the coordinated efforts of a variety of individuals and organizations (Wolf et al., 2022; UN, 2023). As forests play an essential role in sustainable development and have a direct impact on the carbon cycle, climate change, and biodiversity (FAO and UNEP, 2020; Ontl et al., 2018, 2020; Silva et al., 2023; Gutiérrez and Lozano, 2022), they were considered in the original definition of sustainability, and their impacts were integrated into sustainable indicators and metrics (Kadam et al., 2021). For example, the Environmental Performance Index (EPI) aims to measure the environmental health and ecosystem vitality as well as climate change mitigation, both at the national level for hierarchical purposes (Wolf et al., 2022) and Sustainable Development Goals (SDG) give focus to the social, economic, and environmental sustainability (UN, 2023). The emphasis on sustainability addressed by EPI and SDG are very relevant and, as stated in UN 2030 SDG's Agenda: "In sharp contrast to the MDGs, the Sustainable Development Goals (SDGs) are uniformly applicable to all countries of the world, removing the "developing "concept in sustainability criteria.

The forest sector must be sustainable and resilient in all its aspects including economically, and the certification procedures comprise additional costs to producers and forest managers (Michal et al., 2019b). The standards and policies related to forest sustainability are based on the concept that investing in sustainable forests can result not only in environmental but also in economic benefits (WEF, 2021). It is this potential valorization and economic return that is yet undefined and that needs to be further investigated. A recent study found mixed results regarding the economic viability of forest certification. It noted that while there are generally positive impacts on forest management practices, the economic benefits are less clear and often vary by region and certification scheme (Wolff and Schweinle, 2022). In Europe there is a limited understanding of the economic impacts of forest certification at country level. While much research has focused on the environmental and social benefits of forest certification (Rametsteiner and Simula, 2003; Ghazoul, 2001; Lehtonen et al., 2021; Elbakidze et al., 2016; Hain and Ahas, 2011; Ozinga, 2004; Mikulková et al., 2015; Ghidiu Bîta, 2011), there is still insufficient data on the economic viability of forest certification for forest owners, managers, and investors. It is not well understood how certification contributes to the overall economic growth in the European forest sector. Research specifically focused on the economic constraints and benefits of certification remains crucial. Understanding the economic implications and potential benefits of forest certification is essential for forest owners, managers, and investors. This economic perspective is not only important for encouraging greater adoption of certification schemes but also for ensuring that they can be scaled effectively. By providing valuable insights into the financial viability and profitability of certified forestry, such studies can help stakeholders make informed decisions, thus supporting the growth of sustainable forest practices while balancing environmental and economic objectives.

This study provides a comprehensive analysis of forest certification across Europe by combining economic and environmental indicators at country level. While previous studies have examined individual aspects of certification, such as its impact on sustainable forest management or environmental conservation (Ghazoul, 2001; Lehtonen et al., 2021; Elbakidze et al., 2016; Hain and Ahas, 2011; Ozinga, 2004; Lombardo and Maetzke, 2019; Kadam et al., 2021; Malovrh et al., 2019; Paluš et al., 2018; Rametsteiner and Simula, 2003;

Dias et al., 2013; Melo et al., 2014), this study aims to help bridging the existing gap by exploring the connections between certified forest areas and economic indicators across different countries. Additionally, it uses a broad range of data sources, including technical reports and public data, to provide a nuanced understanding of how forest management practices and certification schemes influence national economic performance in the forest sector. The aim of this study is to provide an analysis of the levels of forest certification across Europe and identify potential correlations between certified forest areas and economic indicators related the forest sector, at country level. Particularly, the objectives of this study are (1) to evaluate the extent of forest certification across different European countries, focusing on the variation in certified forest areas and (2) to explore potential relationships between the amount of certified forest area and key economic and environmental indicators related to the forest sector at the country level. In this context, the present study explores the available information from technical reports, policy documents, and other reliable public data sources associated with forest certification and related economic indicators by country in Europe and infers the impacts they have depending on the types of forest management and certification schemes in the different member states.

2 Materials and methods

2.1 Data selection, collection and preparation

2.1.1 Total forest and certified forest areas

Data related to total land area, total forest area and total certified forest area for the year 2020 and for each European country were collected from FAO (2024) database; the forest area certified according to PEFC International (2020) and FSC (2024) standards were obtained from the respective institutional sites. Although some forest areas may be certified according to the standards of both schemes, this was not taken into consideration. To avoid overlapping of certified areas, total certified forest area was obtained from FAO (2024). The year 2020 was selected as the reference year due to data availability to all the selected indicators and countries (Supplementary Table S1). The percentage (%) of forest area was obtained by dividing the total forest area of each country (1,000 ha) by the respective total land area (1,000 ha). The percentage (%) of total certified forest area, of the certified forest area by PEFC and, of the certified forest area by FSC were determined by dividing the respective variable (1,000 ha) by the total forest area of each country.

2.1.2 Economic indicators

The 'Economic aggregates of forestry' (Eurostat, 2023) data set was used (Equations 1–5). However, considering the missing values in this dataset criteria to balance economic consumption variables and output variables were used to understand their links to certified forest area (Supplementary Table S2). Therefore, intermediate consumption (IC) and consumption of fixed capital (CFC) in forestry were chosen as economic consumption variables. While the IC measures the value of goods and services consumed as inputs in forest, the CFC measures the depreciation of fixed assets used in forestry, working as proxies to costs. We should note that in the absence of data on gross fixed capital formation in forests (i.e., investment in forests), CFC provides an indication of the investment flow in tangible assets by country, such as infrastructure, machinery, and other physical resources that contribute to forest certification efforts. These physical assets play a vital role in supporting sustainable forest management practices. However, CFC primarily captures investments in such tangible assets and does not reflect knowledge-intensive or intangible investments, such as those related to risk management, reputation enhancement, and brand positioning, which are equally crucial for maximizing the value and sustainability of forest certification.

As for the output variables, the 'outputs from the forest sector and related secondary activities' (OFSRSA) and the gross value added (GVA) were considered (Eurostat, 2023) as proxies to economic gains. The output metric (OFSRSA) refers to the value of goods and services produced at basic prices in the forest sector, excluding taxes and subsidies. As a measure of productivity, GVA captures the gross contribution of forestry to an economy by calculating the value of OFSRSA minus the cost of IC:

$$GVA_i = OFSRSA_i - IC_i, \tag{1}$$

where i corresponds to each country in analysis.

This economic approach closes with the presentation of the net value added (NVA) in the forest sector, which captures the output values minus both IC and CFC (aggregate consumption—AC), closely relating as a proxy to net profit which can be described analytically as:

$$NVA_i = OFSRSA_i - \left(IC_i + CFC_{i.}\right)$$

$$\left\langle = \right\rangle NVA_i = OFSRSA_i - AC_i, \tag{2}$$

where i corresponds to each country in analysis.

This brings us to this relation between the variables representing the gradual consumption of forest resources, as in any other economic sector along the value chain, where gross expenditures lose value:

$$OFSRSA_i > GVA_i > NVA_i, \tag{3}$$

where i corresponds to each country in analysis.

The economic indicators for the year 2020 (1) intermediate consumption (million euros), (2) the gross value added (GVA) (million euros), and the (3) outputs from the forest sector and related secondary activities (million euros), were extracted from Eurostat (2023) as stated above. The GVA represents the contribution of each sector, in this case of the forest sector, to the economy of a country by calculating the value of the output of the sector minus the cost of intermediate consumption (Eurostat, 2023). The economic indicators are defined, on average, by forest area, and have, therefore, been weighted by the proportion of certified forest area for countries in 2020[1]:

$$WEI_i = \frac{EI_i}{forest\ area_i} \times certified\ forest\ area_i, \tag{4}$$

1 For the United Kingdom, the latest data available is for 2018.

where *WEI* is each weighted economic indicator measured by the corresponding economic indicator belonging to country *i*.

2.1.3 Environmental indicators

Data related to environmental indicators were obtained from the Environmental performance index (EPI) database Wolf et al. (2022) and from the UN (2024). The selected environmental indicators were EPI and the terrestrial biome protection, global, in biodiversity and habitat (TBG) (Wolf et al., 2022) both for the year 2020 (Wolf et al., 2022). SDG 15, protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss, was also addressed through SDG15.2.1 targets: proportion of forest area within legally established protected areas for the year 2020 and proportion of forest area under a long-term management plan (UN, 2024) (Supplementary Table S3).

2.1.4 Selected countries

Due to the statistics available for the chosen indicators and variables, 28 European countries were selected and further investigated in the present study: Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK).

2.2 Data analysis

To analyze the relationship between the certified forest area and various economic indicators of the forestry sector, a correlation analysis was conducted using the collected data. The analysis focused on the four specific economic indicators: intermediate consumption (€.ha^{-1}), consumption of fixed capital (€.ha^{-1}), gross value added (GVA) (€.ha^{-1}), and outputs from the forest sector and related secondary activities (OFSRSA) (€.ha^{-1}). The data was then visualized using scatter plots to facilitate interpretation and comparison. Given our small sample of 28 countries, the non-parametric correlation methods such as Spearman's Rank Correlation or Kendall's Tau-b are more adequate, rather than a parametric method like Pearson's correlation (Gibbons and Chakraborti, 2011). Additionally, Kendall's Tau-b is preferred over Spearman's correlation, as recommended by Croux and Dehon (2010), for smaller samples. Hence, for analyzing the relationship between certified forest (*CF*) and economic indicators (EIs), we employ Kendall's Tau-b correlation method:

$$\tau_b = \frac{(C - D)}{\sqrt{(n_{cf} - T_{cf})(n_{ei} - T_{ei})}}, \quad (5)$$

where *C* is the number of concordant pairs, *D* refers to the number of discordant pairs, n_{cf} denotes the total number of observations in *CF*, n_{ei} indicates the total number of observations in each EI, T_{cf} represents the number of ties in *CF*, and T_{ei} refers to the number of ties in each EI.

3 Results

3.1 Forest area and certification status

To first understand the geographical distribution of forest land cover and its relation to FSC and PEFC certified forest area, FAO (2024), PEFC International (2020) and FSC (2024) databases were screened, and data was extracted by European country. According to data from FAO (2024), the average amount of forest coverage in the 28 European countries that were screened corresponded to 36% of the total country land area, with 15 of those countries having a forest area between 30 and 40%. Finland, Sweden, and Slovenia were the countries with the largest percentage of forested area in the European Continent, reaching the highest value of 74% in Finland and 69% in Sweden. The countries with the lowest percentage of forest area were the Netherlands and Ireland with the forest land use corresponding to *circa* 11% of the land area (Figure 1).

In comparison to the area covered by forest, the analysis of the proportion of certified forest area published by FAO (2024) in each of the 28 European countries revealed an interesting pattern. By having all its forest certified (100%) according to the standards of at least one of the two organizations, FSC and PEFC, Croatia had the highest proportion of certified forest area followed by Bosnia and Herzegovina (86%). Austria (83%) and Finland (82%) each had more than 80% of forest certified area. Italy, Spain, Hungary, and Portugal had the lowest percentage of certified forest land, with numbers ranging from 9% in Italy to 15% in Hungary and Portugal. Czechia and the Netherlands have values of certified forest closer to the average of 51%, with 69 and 46% of area certified, respectively. The average certified forest area among the 28 nations was 51% (Figure 2). More than 50% of the forest area in 15 of the 28 nations has already received FSC and/or PEFC certification.

According to data extracted from the FSC database (Ghazoul, 2001), the average amount of forest land in the chosen countries that had been FSC certified was 34%, with 10 countries accounting for more than 50% of the total forested land. The entire forest area in Croatia has FSC certification, and in Sweden and Bosnia and Herzegovina, where the percentage of certified forest land relative to the total national forest land according to FSC standards has reached 66 and 83%, respectively. No forest area in Austria is FSC certified and had a negligible (less or equal to 1%) presence in France and Italy (Figure 3).

A different profile for PEFC certification was observed. Of the selected countries, 11 have more than 50% of their total forest cover certified according to the standards of PEFC, which on average certified 36% of their forested area, slightly above FSC range (34%). This programme has a higher presence in Austria and Finland, being 85 and 83%, respectively, certified according to PEFC standards in those countries. Czechia has 67% of the forest area with PEFC certification, while only 5% is certified according to the standards of FSC. In Slovenia and Bosnia and Herzegovina, no forest area was certified according to the standards of PEFC. In Romania and the Netherlands this organization certified 1% of the

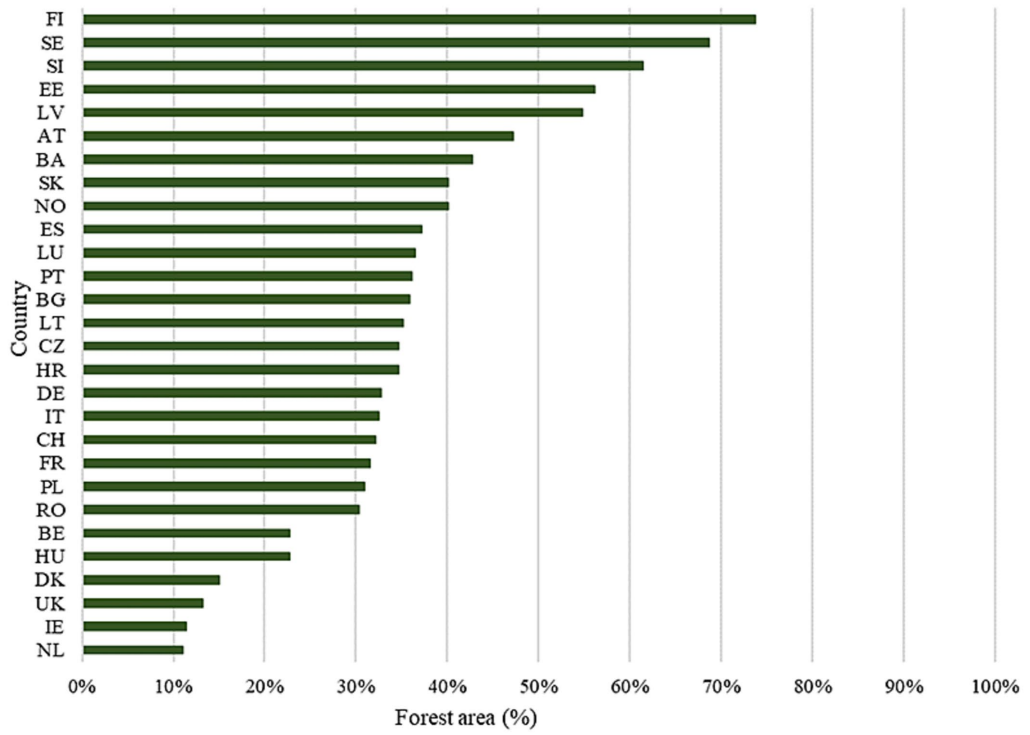

FIGURE 1
Total forest area by country in Europe, in terms of percentage of the total country land area, obtained as the ratio between the total forest area (ha) and the total country land area (ha) of each of the European countries Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK). Source of the original dataset (FAO, 2024).

forest area (Figure 4), while the remain certified forest area was FSC certified. The United Kingdom and Ireland had almost equal percentages of their total forest area certified according to the two programmes: in The United Kingdom, 50% of the forest was FSC certified, while 48% was PEFC certified, and 58% of the entire forest area in Ireland was certified according to the standards of both organizations.

3.2 Forest certification status and economic indicators

The relationship between intermediate consumption and the proportion of certified forest land demonstrated an increased tendency for certified forest area to correlate with higher costs. When the certified area reached 70% or more, the cost per ha tended to decline. Czechia with 69% forest certification area and an intermediate consumption of 466 €. ha^{-1} (Figure 5).

Only Switzerland and Denmark showed a consumption of fixed capital above of 50 €. ha^{-1}. This fact indicates a higher amount of fixed assets used repeatedly on the certified forest area in these countries compared to the other countries analyzed. Curious is also the fact that these two countries are amongst those that show a higher intermediate consumption cost too (Figure 5).

The relationship between consumption of fixed capital and the proportion of certified forest land demonstrated, as expected, an increased tendency for certified forest area to correlate with depreciation of fixed assets, because of its normal wear and tear and obsolescence in forests (Figure 6).

The analysis of the relation between the forest outputs and related secondary activities revealed an increase in revenues proportional to the percentage of certified forest within each country, particularly evident in countries with low certification values and low incomes. The relation was not so clear when the percentage of certified area increased. However, it was possible to observe a tendency for the revenues to plateau after at least 70% of the forest had received certification. Once more, Czechia was out the general trend reporting the highest output, 701 €. ha^{-1}. Netherland and Denmark presented the following higher values, 430 €. ha^{-1} and 421€. ha^{-1}, respectively. In contrast, Croatia, which had all its forested land certified, recorded relatively low income, comparable to that of nations with 30 to 40% of forest certified (Figure 7).

The percentage of certified forest land and GVA showed a positive correlation, with this indicator rising exponentially as the percentage of certified forest area increased. The tendency is clearer until reaching 50% of forest with certification. Countries with higher values of certified forest, presented more distinct patterns (Figure 8).

Overall, it is possible to examine the correlation between the certified forest area and each economic indicator based on its characteristics. There is a positive and statistically significant association between the certification area and economic indicators in forestry, whether related to consumption (cost) or valuable output

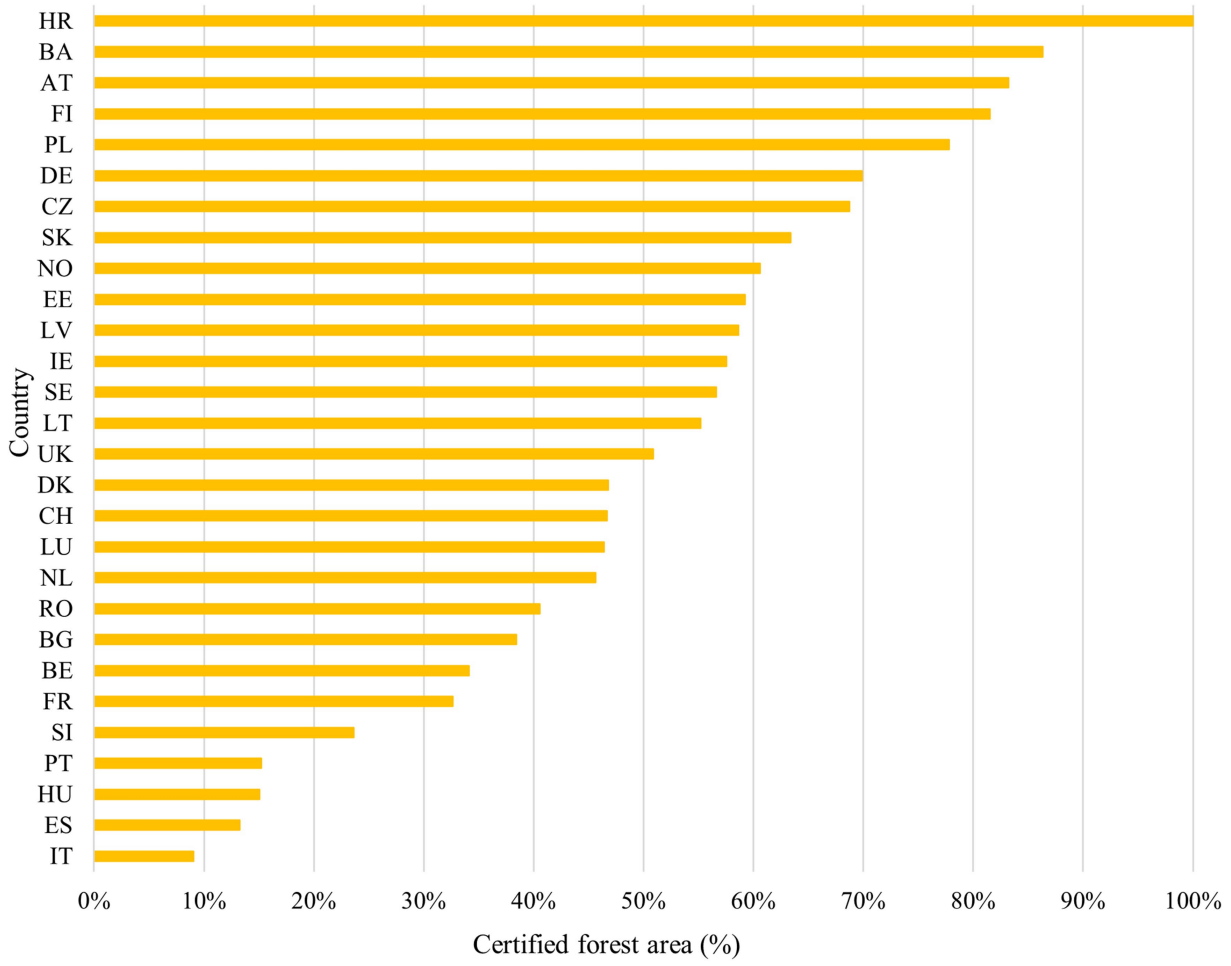

FIGURE 2
Certified forest area, as percentage of the total forest area, by country in Europe, obtained as the ratio between the total certified forest area (ha) and the total forest area (ha) of each of the European countries Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK). Source of the original dataset (FAO, 2024).

(gain) (Table 1). According to Ratner (2009), this indicates a moderate linear relationship between certificate area and economic indicators. This means that as the certification area expands, both the consumption (cost) and the economic output of the forest increase. The correlation between forest certification and the economic indicators is still moderately positive. Nevertheless, the correlation is stronger in terms of output variables (gain), when compared to the correlation with input variables.

Based on a more detailed analysis, Figure 9 confirms that the selected countries in the first quartile of certified forest area [Croatia, Bosnia and Herzegovina, Austria, Finland, Poland, Germany, Czechia] generated, on average, a NVA of 128.95 (€. ha^{-1}) from their certified forest area in 2020. In contrast, the selected countries in the fourth (or last) quartile of certified forest area [Belgium, France, Slovenia, Portugal, Hungary, Spain, Italy] had an average NVA of 28.58 (€. ha^{-1}) for their certified forest area in 2020. Particular attention should be paid to the Czechia in comparison to the Netherlands, as they both have a similar NVA despite having completely different certified forest areas. This result may be justified by some national differences in the quantification of the economic indicator. Interestingly, Bosnia and Herzegovina has the NVA closest to the (gross) output of certified forest area.

The results also show that higher levels of net value added are associated with higher levels of certified forest area (Figure 9). In addition, all countries had a positive net value added, regardless of certified forest area.

3.3 Forest certification status and indicators for environmental sustainability (EPI and SDG 15)

Regarding the EPI, the 28 countries had in average a score of 61, with Denmark and United Kingdom presenting the highest values, 77.9 and 77.7, respectively. All countries had values of EPI higher than 50, regardless the percentage of certified forest area, except for Bosnia and Herzegovina with a value of 39.4 and 86% of certified forest (Figure 10). The indicator for terrestrial biome protection,

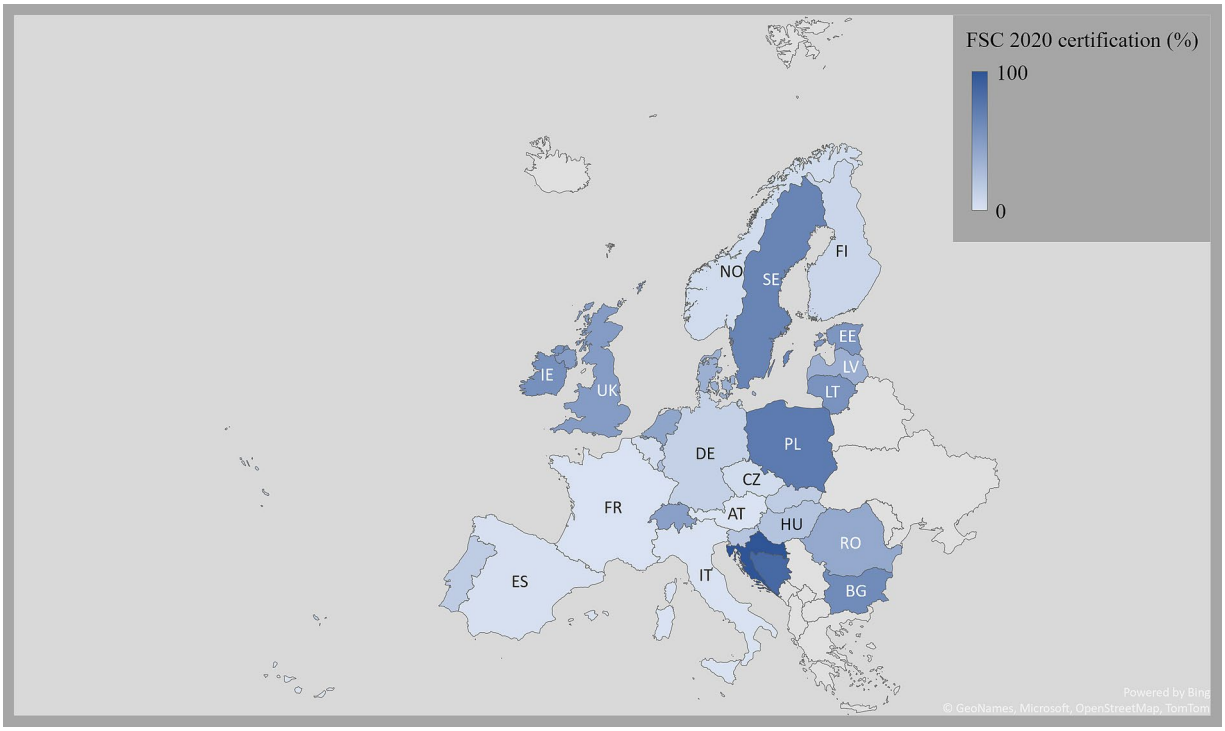

FIGURE 3
Forest area with FSC certification, as percentage of the total certified forest area, by country, obtained as the ratio between the area certified according to the standards of FSC and the total certified forest area for the year 2020 of each of the European countries Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK). Source of the original dataset of the certified forest area by country (FAO, 2024) and of the area certified according to the standards of FSC (Ghazoul, 2001).

global, in biodiversity and habitat (EPI—TBG) had a mean value of 16 related to all the 28 countries investigated. Within those countries, 19 had the equal and maximum value observed of 17. The minimum value was reported to Bosnia and Herzegovina with the value 4.5 (Figure 10).

In relation to SDG 15, target 15.2.1 related to the proportion of forest area within legally established protected areas, as well as the proportion of forest area under a long-term management plan (Figure 11). A long-term management plan, as defined by SDG 15, target 15.2.1, is a strategic framework designed to ensure sustainable forest management, conservation, and resource use over an extended period, typically spanning multiple decades (UN, 2023). Results reflect the progression of the countries towards sustainable forest management (UN, 2023, 2024). The average for all countries in terms of the forest area within legally established protected areas was 20%, with 13 nations above average. The highest percentage was reported by the Netherlands with 60%, and the lowest percentage by Croatia with 3%. It is worthy to note that the trend among the countries with less than 50% certified forest is that the percentage of protected areas (SDG 15, target 15.2.1) tend to have the same pattern as the percentage of certified forest area. The exception were Italy and Spain, where the percentage of protected forest highly exceed the percentage of forest with certification (Figure 11). The target proportion of forest area under a long-term management plan (SDG 15, target 15.2.1) had an average value across all nations of 67%. Eight nations—Croatia, Finland, Czechia, Slovakia, Latvia, Lithuania, Slovenia, and Hungary—getting as high as 100% by the year 2020. Portugal reported the lower number, 27%, as its reference value. All the countries, except for three, reported percentages of forested areas under long-term management plans equal to, or higher than, their respective percentage of certified areas. Austria had the higher gap between this indication (50%) and the certified forest area (83%). Regarding this target, no data was available for Italy, Luxembourg and Bosnia and Herzegovina (Figure 11).

4 Discussion

The forest coverage and the certified forest area varied greatly across European nations, as well as their related economic indicators. This fact results from a variety of reasons such as, but not only, different types of forests, landscapes and climates, distinct ownership and management approaches, and diverse national forest policies (Kauppi et al., 2022). Despite variations in forest coverage across countries, statistics showed that between 2000 and 2018, the quality of more than 60% of the forest in Europe has increased (Maes et al., 2023). Forest certification has made significant progress in Europe by promoting sustainable forest management practices (FOREST EUROPE, 2020; EIB, 2022), a concept that has been growing in acceptance and popularity in both national forest plans and international forest policy (MacDicken et al., 2015). Our results demonstrated that the pattern observed within European countries in

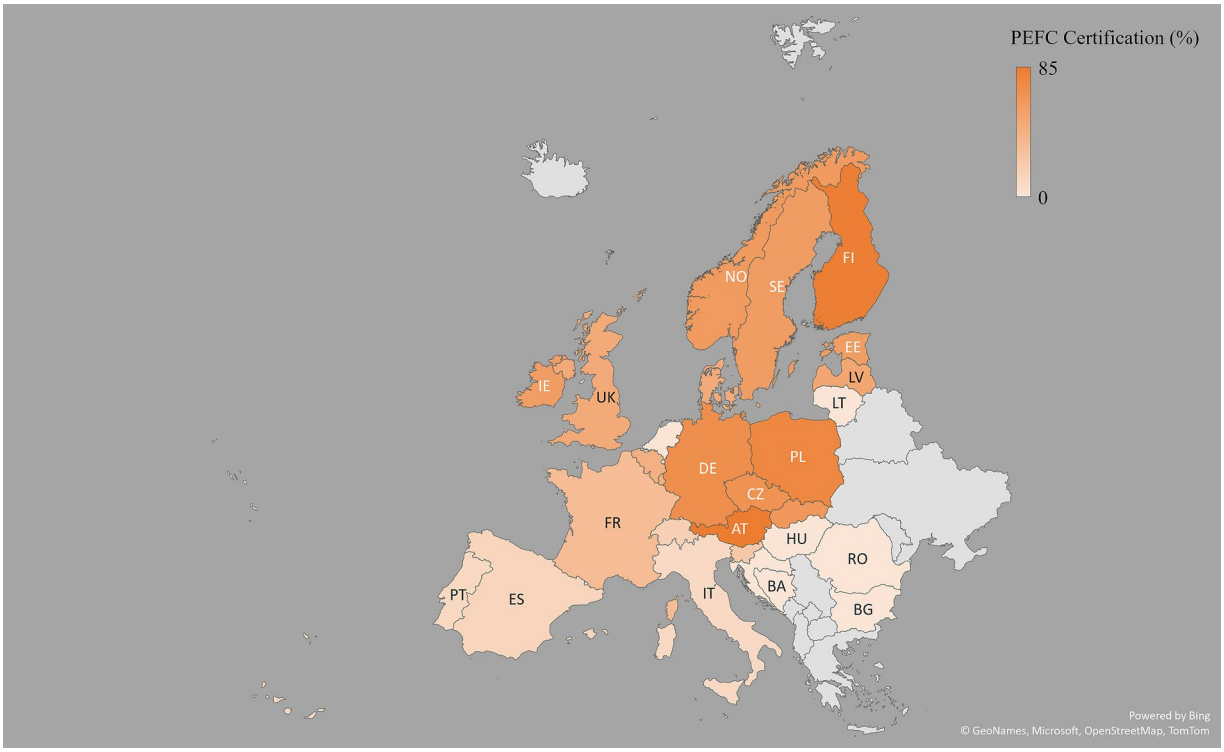

FIGURE 4
Forest area with PEFC certification, as percentage of the total certified forest area, by country, obtained as the ratio between the area certified according to the standards of PEFC and the total certified forest area for the year 2020 of each of the European countries Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK). Source of the original dataset of the certified forest area by country (FAO, 2024) and of the area certified according to the standards of PEFC (PEFC International, 2020).

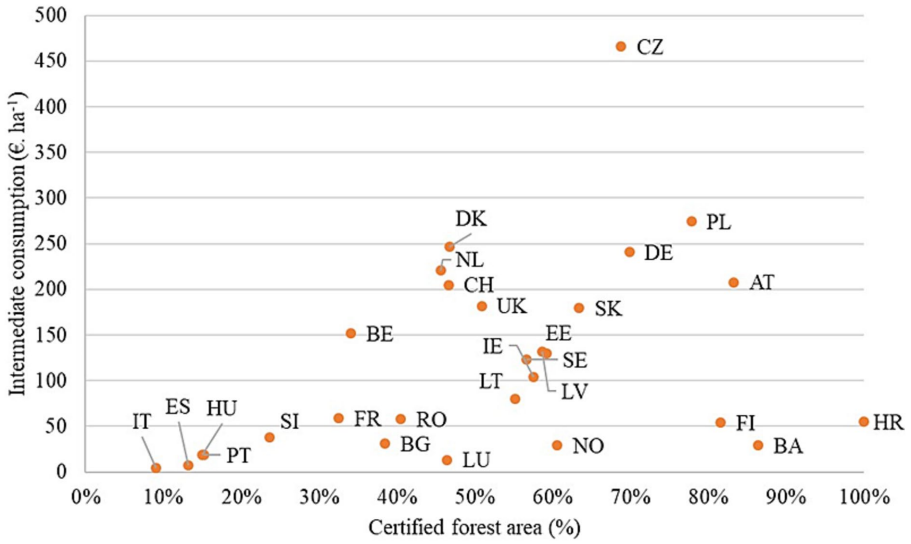

FIGURE 5
Relation between the intermediate consumption in 2020 by country, in euros per ha, and the respective certified forest area for the European countries Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK). The original data for the intermediate consumption was obtained from Eurostat (2023) and the certified forest area was obtained from FAO (2024).

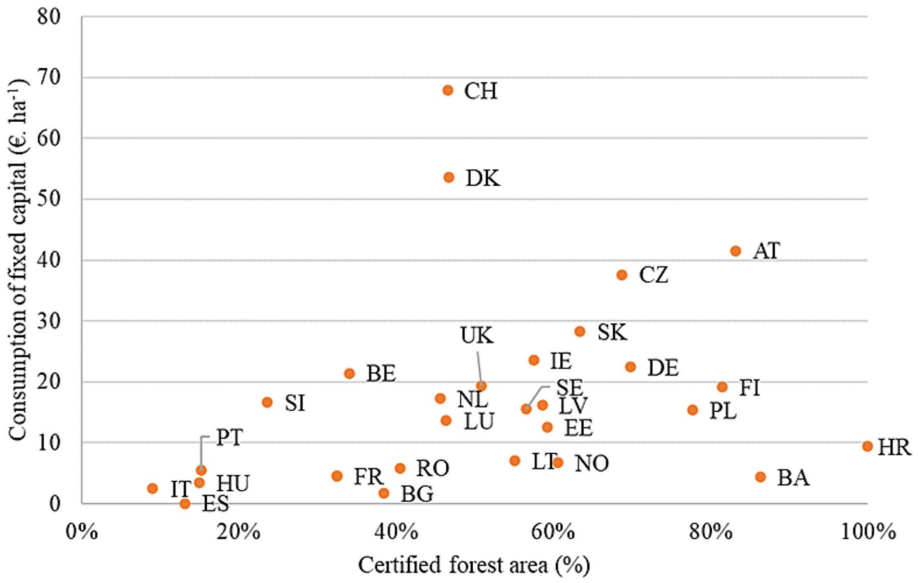

FIGURE 6
Relation between the consumption of fixed capital in 2020 by country, in euros per ha, and the respective certified forest area for the European countries Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK). The original data for the consumption of fixed capital was obtained from Eurostat (2023) and the certified forest area was obtained from FAO (2024).

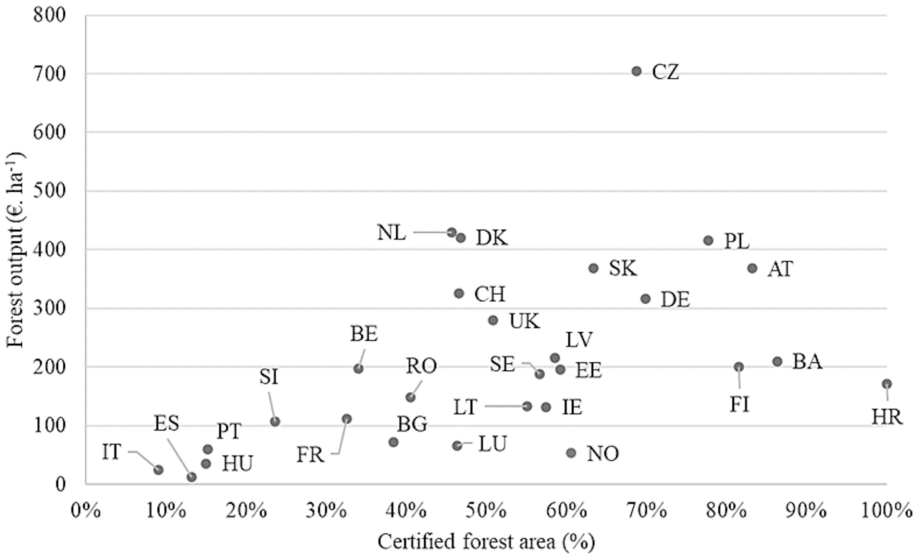

FIGURE 7
Relation between the output generated by the forestry sector and related secondary activities in 2020 by country, in euros per ha, and the respective certified forest area for the European countries Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK). The original data for the output of forestry and connected secondary activities was obtained from Eurostat (2023) and the certified forest area was obtained from (FAO, 2024).

relation to forest coverage is not yet fully reflected in the proportion of certified forests (Figure 12). Even though Finland had the highest percentage of forest area and more than 80% of certified forests, Croatia, Bosnia and Herzegovina, and Austria, despite having lower forest cover had even higher certification rates. Several studies on forest certification have highlighted some of its environmental, social, and economic impacts (Lehtonen et al., 2021; Elbakidze et al., 2016; Loveridge et al., 2021; Wiersum et al., 2013; Skulska et al., 2020; Sánchez-Almendro et al., 2018). For example, Lehtonen et al. (2021) reinforced that certification schemes significantly contribute to

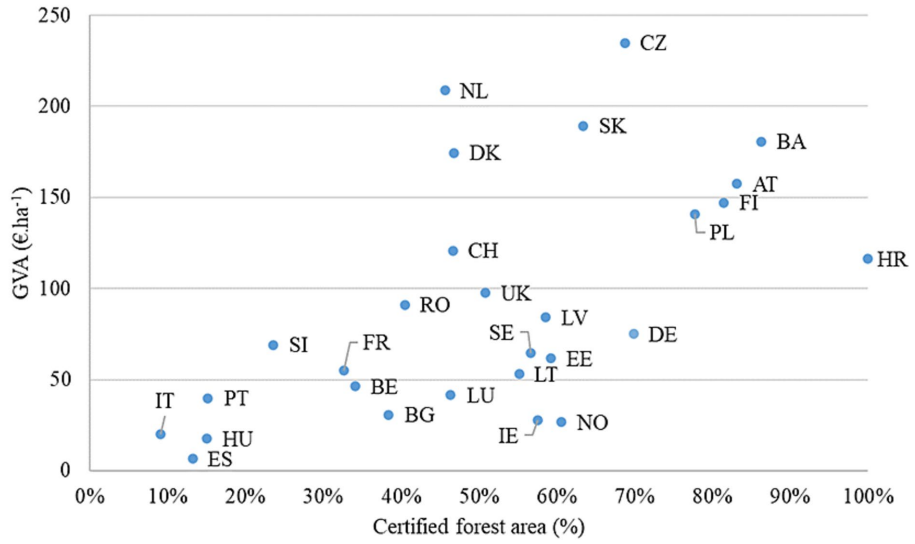

FIGURE 8
Relation between the Gross value added (GVA) in 2020 by country, in euros per ha, and the respective certified forest area for the European countries Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK). The original data for the GVA was obtained from Eurostat (2023) and the certified forest area was obtained from FAO (2024).

TABLE 1 Kendall's Tau b correlation between forest certification area and economic indicators.

Variables nature	Economic indicators	Correlation coefficient
Consumption (Input)	IC	0.376***
	CFC	0.296**
Output	GVA	0.434***
	OFSRSA	0.418***

***p-value < 0.01, **p-value < 0.05.

enhance biodiversity conservation and protection of ecosystem services. Similarly, Loveridge et al. (2021) emphasized that certification promotes better labor opportunities, human welfare and community engagement, although the social benefits are often more pronounced in regions where forest s are owned, managed, or used by local communities. Although various studies have addressed the economic impacts of certification (Wolff and Schweinle, 2022; Muthoo, 2012; Zubizarreta et al., 2023; Panico et al., 2022; Rametsteiner, 2002), results and outcomes remain unclear.

More than 98 million hectares of the European forest, representing around 50% of the total forest area in Europe, are certified according to one or both two certification schemes, FSC (2023) and PEFC (2014, 2023), with more area PEFC certified than FSC within the analyzed countries. Results from this work indicated also that few countries were certified according to the two organizations at equivalent rates, most of the countries presented a prevalence of one of the certification schemes and the drivers and motivations for these might also be relevant for additional insights into policy instruments to drive sustainable forest management. This last result agrees with the findings reported by other authors (Maesano et al., 2018; Gomez-Zamalloa et al., 2011; McDermott et al., 2023). Some countries continue to have a more common certification standard (e.g., in Austria and Finland is more frequently used the PEFC, and in Croatia prevails the FSC). Other countries, like Ireland, have an almost equal percentage of forest with certification from both organizations. Ireland and Portugal who, according to Maesano et al. (2018), had no forest area with PEFC certification, now present forest certified according to the standards of this organization (59 and 10% respectively) obtained since 2004 (PEFC Portugal, 2024). Increasing the share of PEFC certified forests may have specific strategic, economic, and regional considerations (Michal et al., 2019a,b). PEFC was established with strong support from European forest owners and industry stakeholders, particularly in countries where it continues to hold a leading position, such as Austria and Finland, to mitigate challenges faced by The adequacy of FSC and PEFC standards, which integrate adaptability to local conditions and group certification mechanisms as strong features (Zubizarreta et al., 2024; Eggers et al., 2014), varies based on the environmental and socioeconomic context of a nation or sector, as well as the stakeholder perspectives on effectively addressing the main obstacles of forest certification (McDermott et al., 2023). In countries like Croatia, where most of the forest is managed by the state (Halder et al., 2014), forest certification is frequently considered as a means of validating the quality and competence of state forest management organizations (Cashore et al., 2006), but also one of the major procedures influencing wood exports (Bičanić et al., 2011). Particularly, FSC certification in Croatia plays a crucial role in enhancing their wood market competitiveness and exports (Klarić et al., 2016). On the other hand, the external credibility of companies with greater efficiency and economic profitability, as well as the access to international markets, have been significant drivers of entry into PEFC certification (Zubizarreta et al., 2021; Paluš et al., 2019). This tendency to increase the presence of both standards in many European

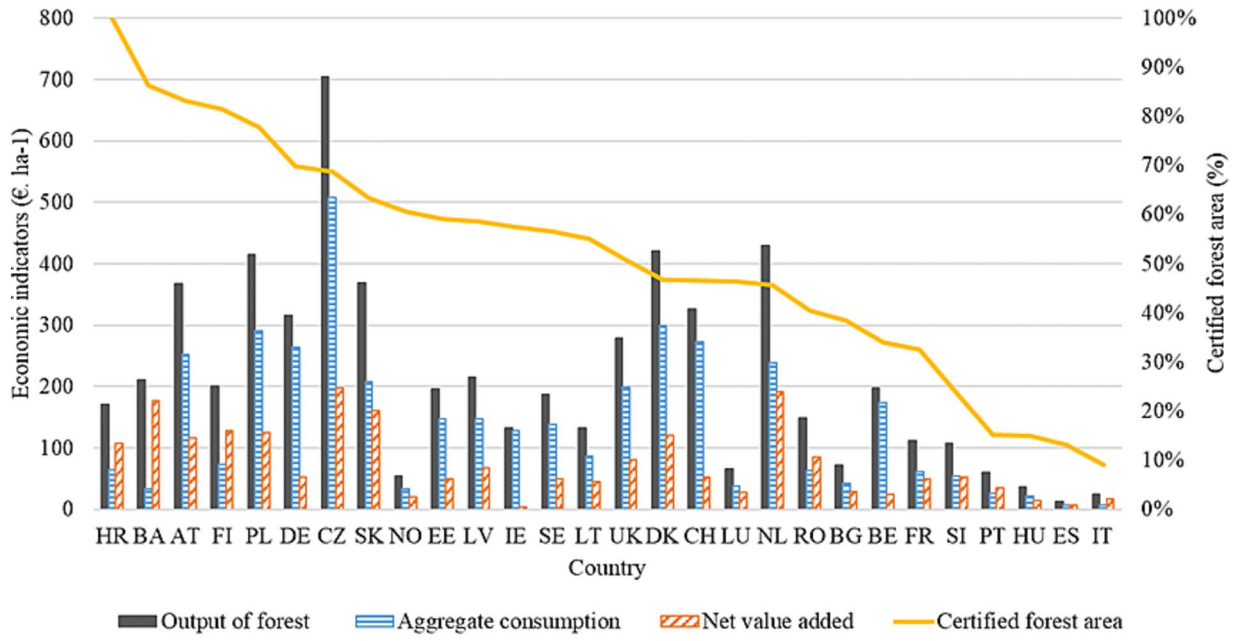

FIGURE 9
Certified forest area (%, yellow line), output of forest and connected secondary activities (€. ha^{-1}; grey bars), aggregate consumption (€. ha^{-1}; blue bars), and net value added (€. ha^{-1}; orange bars), all for the year of 2020 and for the European countries Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK). The original data for the output of forest and related secondary activities, aggregate consumption, and NVA were obtained from Eurostat (2023) and the total forest area and the certified forest area was obtained from FAO (2024).

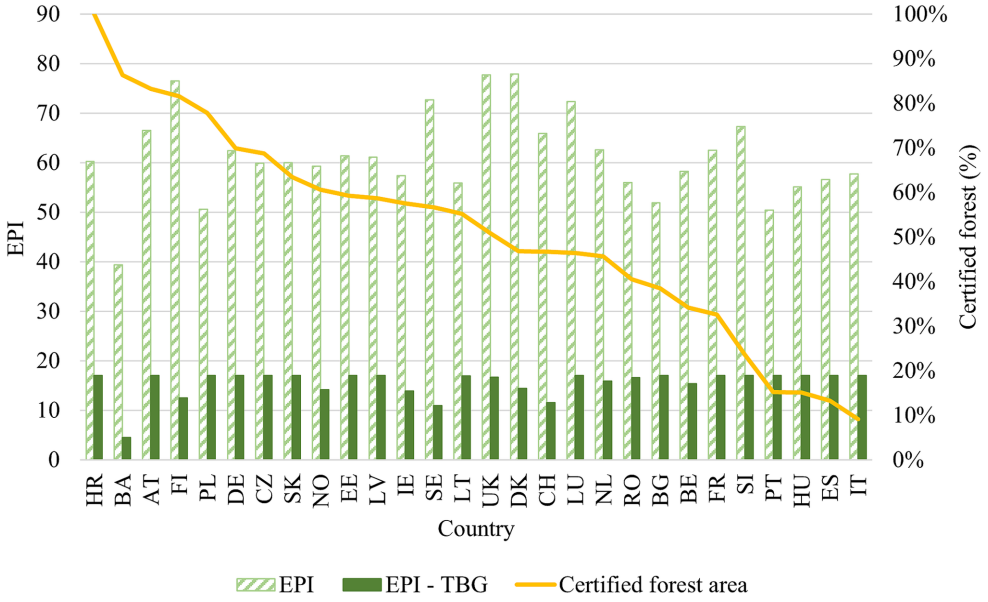

FIGURE 10
Environmental performance index (EPI) for the year 2020 (light green bars) and terrestrial biome protection, global, in biodiversity and habitat (EPI – TBG) for the year 2020 (dark green bars), and by country and the respective certified forest area (%, yellow line) for the European countries Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK). The original data for the EPI 2022 was obtained from (Wolf et al., 2022) and the certified forest area was obtained from (FAO, 2024).

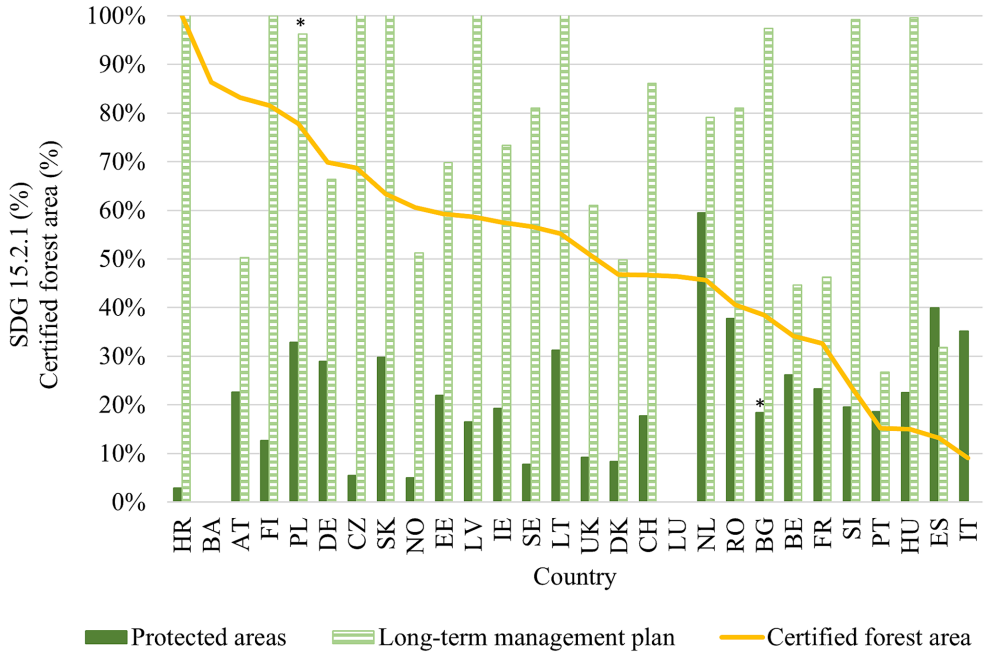

FIGURE 11
Sustainable development goal (SDG) 15.2.1 targets of the proportion of forest area within legally established protected areas for the year of 2020 (%, dark green bars) and of proportion of forest area under a long-term management plan for the year of 2020 (%, light green bars), and the respective certified forest area (%, yellow line) for the European countries Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK). The original data for the SDG 15.2.1 indicator was obtained from UN (2023) and the certified forest area was obtained from (FAO, 2024). The asterisk (*) indicates countries whose last data was reported between 2015 and 2018.

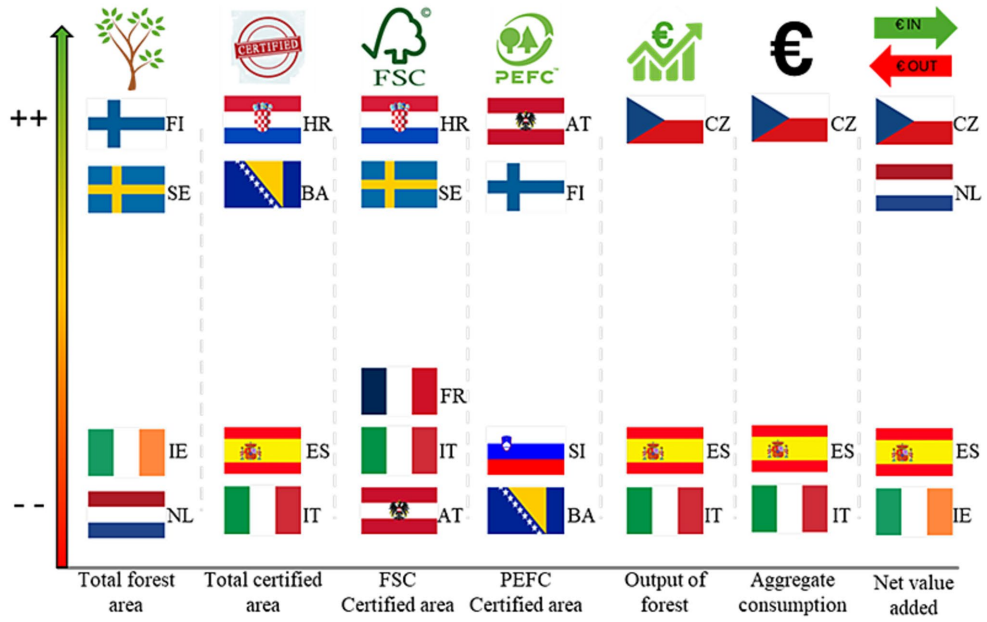

FIGURE 12
Overview for the European countries [Austria (AT), Belgium (BE), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Czechia (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK)], with the highest and lowest total forestry area, total certified forest area, certified forest area by FSC and PEFC, total outputs from forests, aggregate consumption, and net value added.

countries is often a requirement to have access to international markets and a response of companies to the market trends, as the two schemes have no mutual recognition (Maesano et al., 2018; Zubizarreta et al., 2023; Burivalova et al., 2017) and different consumer markets may prefer different certification brands.

From an economic perspective, Czechia stood out as the country with a higher expense (IC) for certified forest area, but also with larger outputs from forest sector and connected secondary activities. These results may be justified by the implementation of historical national policies that favored conventional management techniques, focusing mostly on the production of timber and other wood products instead of more ecologic-oriented management models (Fanta and Petřík, 2018). The levels of those variables were noticeably lower in Italy and Spain. According to Martinho and Ferreira (2021), the production obtained from forest-related activities for the period of 2012–2017 was higher in Germany, Czechia, Slovakia, Austria, and Slovenia when weighted by the total land area of the respective country. Considering total revenues for that period (2012–2017), France, Germany, and Sweden proved to have the capacity to successfully explore economically their forest land (Martinho and Ferreira, 2021). Both studies supported the importance of forests in Czechia, but weighting the economic indicators by the ratio of certified forest area it was possible to better understand the dynamic between forest certification and the economy of the sector in that country. As expected, results from the current study indicated that in terms of GVA and NVA, Czechia continued to be the top-ranked nation, followed by Netherlands and Slovakia. Croatia, a country with all its forest land FSC certified, had a mean GVA value (116 €. ha^{-1}), suggesting some inefficiency to successfully and fully explore, and increase the outcomes, of its forested territory. Such economic pattern may be the effect of (lack of) internal policies, adequate incentives, and the predominance of the public ownership of the forest territory (Halder et al., 2014).

The results also show that CFC is higher at the high-income countries, such as Switzerland or Denmark. As CFC values are much lower than IC values, this may suggest that investment is needed in forestry sector, as claimed by authors in different regions (Brancalion et al., 2017; Degnet et al., 2018). Forest certification has been identified as one of the main factors that might contribute for supporting the investment in forestry (Chudy and Cubbage, 2020); yet objective data regarding the measurement of the amount of investment that forest certification fosters is lacking. Additionally, a rise in investment and the formation of green jobs has also been observed in nations with variable levels of forest coverage, from those with little to those with a large and established portion of their territory covered by forest (Martinho and Ferreira, 2021). In fact, forest and forest management have become further economically relevant as the result of the high number of jobs associated with the forest industry and the rising demand for certified and sustainably managed forest derived products from significant international markets for timber and pulpwood (Kauppi et al., 2022; Chudy and Cubbage, 2020).

The overall analysis of both consumption expenditures variables (IC and CFC) demonstrated a tendency for costs to rise along with the increment of certified forest area, supporting the fact that the certification process is often expensive, particularly at a small scale (Maesano et al., 2018; Di Lallo et al., 2016). However, this rise tends to plateau after a certain scale is reached within certification coverage (e.g., around 70% area certified) probably implying that it is indeed possible to sustain at scale a profitable certification scheme where costs are controlled, and outputs may be further increased (Kauppi et al., 2022). The forest output pattern evidenced a positive bias, increasing with the ratio of forest with certification, but quite divergent among countries with more than 50% of the area certified. This is most probably due to not only, different management and exploitation options in each country, but mostly to external conditions specific to each country, such as market access and political and industrial adequate frameworks, as economic benefits of forest certification are varied and context-dependent (Wolff and Schweinle, 2022). In terms of the relationship of both economic gains variables, GVA and NVA to certified forest area, it is generally the case that the more certified forest area, the higher the economic value of the country's forest (Wolff and Schweinle, 2022), which supports market, political and industrial framework in the forestry sector. Our results clearly demonstrate that the correlation between the economic output indicators and forest certification is stronger with the output (gains) variables than with the input (costs) variables. This suggests that certification has a higher influence on the revenues from forests than on the associated costs. This result has, *per se*, a relevant impact on forestry management and can guide decision making processes on the type, extent and model of forest certification scheme to be adopted per country. National governmental authorities and their forest regulations have a significant impact on the economy of the forest sector, but the market context and access in the different European countries is also of crucial importance (Maesano et al., 2018; Cashore et al., 2006). Particularly, markets for timber and pulpwood encourage landowners to make expenditures in forest management to increase not only market value but also forest productivity (Chudy and Cubbage, 2020; Lehtonen et al., 2021; Loveridge et al., 2021; Wolff and Schweinle, 2022; Muthoo, 2012; Zubizarreta et al., 2023; Panico et al., 2022; Rametsteiner, 2002). In the last years, forest certification helped to promote the shift of forest management from timber and productivity to a wider range of other ecosystem services such soil conservation and water regulation, that further impact the productivity of the forests themselves, using novel approaches to forest governance that involve the interaction of public and private stakeholders (Schwaiger et al., 2019; Malek and Abdul Rahim, 2022), targeting goals completely aligned with those established within the EPI and the SDG (Wolf et al., 2022; UN, 2024; FSC, 2023; PEFC, 2023).

The findings from our work show no relation between the EPI (general) and the ratio of certified forest, with all the investigated countries presenting a score equal or higher to 50. The only exception was Bosnia and Herzegovina who scored 39. These results demonstrate the inadequacy of a general indicator like the EPI to address the impacts of forest certification at national level, as the contribution of forest sector is, in some way, diluted within the overall contributions of other sectors impacting the environment, such as ocean or other land-based ecosystems. The EPI ranks 180 nations worldwide on their progress towards enhancing environmental sustainability using 40 performance indicators within 11 categories (Wolf et al., 2022). Results from the EPI-TBG indicator, connected to global protection of terrestrial ecosystems in biodiversity and habitat (Wolf et al., 2022), reinforced the absence of link with the ratio forest certification of the European countries already observed with the general EPI. Countries like Italy and Spain, with *circa* 10% of certified forest area, scored the same value as countries like Lithuania, with 60% of forest with certification, and Croatia, with all its forest certified. Once more,

Bosnia and Herzegovina recorded the lowest value, being the second country in terms of ratio of certified area and EPI-TBG value of 4.5. Not all the terrestrial ecosystems are forest-related, varying greatly in type, number, and dimension across countries. Since EPI aggregates data from countries with wildly varied environmental, social, and economic contexts across continents, it is inaccurate in identifying smaller variances between European countries. In general, European forest ecosystems are productive, well-integrated into surrounding forest ecosystems through ecological corridors, and successfully incorporated into the landscape (Maes et al., 2023). Having a rate of certified forests of nearly 50% across all EU just emphasizes these conclusions. Also, it points out the need to design and define further subsets of more comparable and informative indicators for the European reality.

Higher variation was observed between the selected countries when considering the SDG 15 indicator, target 15.2.1, proportion of forest area within legally established protected areas. This indicator focuses specifically on protected forest areas, which have a different status and focus than certified forest areas. Except for Italy and Spain, where the percentage of protected forest vastly exceeded the percentage of forest with certification, the trend among the nations with less than half of certified forest was for protected areas to follow along with the growth of certified forest area. No trend was seen over that threshold of the certified area. The area of planted forest is growing in Europe, along with the demand for wood and other services as carbon sequestration provided higher by forest plantations in relation to native forests (Freer-Smith et al., 2019; Baral et al., 2016). Although forest plantations are often related to the conservation and recovery of natural forests (Tomé et al., 2021), most of forest plantations are still mainly managed for wood production and tend to have low ratios of protected areas (Brockerhoff et al., 2013). The target addressing the proportion of forest area under a long-term management plan showed that Croatia, Finland, Czechia, Slovakia, Latvia, Lithuania, Slovenia, and Hungary had all their forest area covered by such planning, regardless the percentage of their forest area with certification. Except for Italy, Luxembourg and Bosnia and Herzegovina (no data available), only Austria and Norway had ratios of forest area under a long-term management plan inferior to the certified forest. Scientific studies have highlighted the importance of long-term management plans in ensuring effective forest management: well-developed forest management plans are essential for achieving certification goals and promoting sustainable forestry practices (Rametsteiner and Simula, 2003; FSC, 2023; Florian et al., 2018). Additionally, the quality and implementation of management plans are linked to the effectiveness of certification in addressing mainly environmental and social aspects (Marx and Cuypers, 2010). These findings suggest that, although forest certification can be a main driver in both sustainable commercial exploitation of forest areas, as well as, developing long-lasting management plans, in general, European countries have a main concern to define and implement sustainable management forest strategies beyond forest certification, covering specific protected forest areas. The sustainable management of forest plantations, both at stand and landscape levels, is the most effective way to maintain the economic benefits of forest plantations while promoting their multifunctionality and the synergy between ecosystem services (Freer-Smith et al., 2019; Tomé et al., 2021). Forest certification schemes are critical for enhancing the multifunctionality of forest plantations by ensuring that sustainable practices protect both economic benefits and ecosystem services (Rametsteiner and Simula, 2003; Paluš et al., 2021; Kuuluvainen et al., 2019; Alix-Garcia and Wolff, 2014; Vallauri et al., 2022; Asbjornsen et al., 2022). Certification creates opportunities to monetize ecosystem services through mechanisms such as carbon credits or payments for ecosystem services (Alix-Garcia and Wolff, 2014; Vallauri et al., 2022; Asbjornsen et al., 2022). Italy and Spain have pioneered the certification of forest areas for ecosystem service verification, demonstrating that certification can facilitate new financial incentives for sustainable forest management (Vallauri et al., 2022). The attainment of sustainability in the forest sector in Europe differs significantly between nations (Raihan, 2023). This variation is influenced not only by the level of forest certification, but also by the definition and adoption of case-specific measures and national policies (FOREST EUROPE, 2020; Freer-Smith et al., 2019).

Overall, findings from our study reinforced that certification can help enhance the economic performance of forest investments in Europe, mitigating the risks and improving the trust of investors and allowing the access of forest industries to international and highly competitive markets. Regardless of whether forests are publicly or privately owned, if a sustainable economic gain is desired these results suggest that it is highly recommended that the various actors in the sector move towards forest certification (Wolff and Schweinle, 2022; Thorning and Mark-Herbert, 2022). Although countries with higher forest certification rates were not the ones with the highest economic inputs, Italy and Spain, both presenting the lower forest certification percentual values, were consistently the ones with minor economic revenues from forest. Through complementary methodological approaches, our contribution confirmed the relevance of forest certification in creating economic value for forest sustainable exploitation. Nevertheless, the decision to obtain certification as well as the direction of forest management practices can be strongly influenced by ecological and socioeconomic factors. These factors can operate as certification barriers in areas with less economically productive forests or where there are major obstacles to certification, such as limited resources or access to markets (Becker and Laaksonen-Craig, 2006). Our contribution aims to put the economic benefits of forest certification on the academic agenda and relate them to SDG 15. As our study focuses on the most recent data point (2020), this study acts as a starting point for further research by modelling the linkages between certified forests, economic value and environmental sustainability in a longitudinal approach.

Continuing to monitor forest certification and promote harmonized economic data in the future is crucial to accurately determine the economic impact of forest certification in Europe through specific and robust methods, and to design adequate policies promoting sustainable forest management. However, it is evident that there is a lack of studies more focused on enhancing forest certification and sustainable management with direct economic benefits to their nations. Moreover, the access to more detailed information related to forest certification and the production of forest wood and non-wood products, particularly at spatial scale, along with the development of more specific and adjusted economic indicators is essential for properly quantifying the impact of forest certification. These developments can significantly advance the state of the art and open new lines of research, such as researching regional differences in

certification impact and exploring comparable and adequately measured long-term economic benefits of sustainable forest management practices. Our work provides further insights and a more comprehensive understanding of how forest certification influences economic outcomes in Europe and helps guide future policy and supporting investment decisions.

5 Conclusion

The study demonstrates that forest certification has the potential to enhance the economic performance of European forests and that more accurate data is needed to link certification schemes with direct environmental benefits for nations. Forest certification has a stronger positive impact on economic output (gains) indicators than on economic input (costs) indicators, showing that certification increases revenue generation while having a scale related effect on the costs. Although certification costs rise with forest area they tend to stabilize at larger scales, indicating economic scale sustainability of the certification process, often due to group certification. In practice, forest owners/managers can align their strategies with broader economic trends, optimizing their operations to benefit during economic upturns or mitigating risks during economic downturns. Additionally, forest certification helps to manage and mitigate risks related not only to major environmental and social concerns, such as deforestation, human rights violations, and biodiversity loss, by providing assurance that forest operations are managed in a responsible and sustainable manner, but also reputational risks. Risk mitigation can be particularly relevant for investors who are seeking to align their investments with these values and contribute to positive social and environmental outcomes, but also to more conservative investors, as it supports the production and valorization of timber and non-timber forest products in a responsible manner. Forest certification also leads to favorable social and environmental results by satisfying market demand for sustainable and responsible produced goods and at the same time providing access to international and more demanding markets from European forest managers and products developers. A deeper analysis of the obtained database, specifically correlating economic with environmental indicators, framed with European strategies and policies in place, like LULUCF and the Nature restoration Law, as well as the internal relevant national policies of the selected countries, could help to effectively quantify the degree of impact that forest certification has at European level and how European polices can help boost and balance the economy and sustainability of the forest sector across countries. Moreover, the findings highlight the importance of continuing data monitoring and harmonization, detailed spatial analysis, and developing specific forest related economic indicators to guide effective policy and investment decisions, ensuring long-term economic benefits and sustainability in the forestry sector.

Nevertheless, this work presents some limitations, as well as new opportunities for future research. First, using the year of 2020 as the reference year, mainly justified by data availability, may not provide a comprehensive temporal analysis, and future studies should explore trends over longer periods of time. Secondly, this study excludes social indicators such as, e.g., employment rates, which could offer a more holistic understanding of the impact of forest certification. Furthermore, the study does not account for the role of the different types of forest certification, as for example the Chain of Custody certification, which may be crucial for understanding the broader implications of forest certification.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

SC: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Visualization, Writing – original draft. GB: Formal analysis, Visualization, Writing – review & editing. MT: Methodology, Writing – review & editing. AL: Funding acquisition, Project administration, Writing – review & editing. HV: Conceptualization, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/ffgc.2024.1464837/full#supplementary-material

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