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Centralblatt
für das gesamte
Forstwesen**Comparative evaluation of the forestry sector of the bioeconomy in Greece
(2008–2023)****Vergleichende Bewertung des Forstsektors der Bioökonomie in
Griechenland (2008–2023)**Stefanos Tsiaras^{1*}**Keywords:** Circular economy, forest policy, economic indicators, sustainable development, regional disparities, employment trends**Schlüsselbegriffe:** Kreislaufwirtschaft, Forstpolitik, Wirtschaftsindikatoren, nachhaltige Entwicklung, regionale Disparitäten, Beschäftigungstrends**Abstract**

The forest-based bioeconomy has become a strategic priority in the European Union (EU); however, substantial disparities persist among Member States. This study evaluates Greece's performance in the forestry sector of the bioeconomy over the period 2008–2023, using harmonized data from the European Commission's Bioeconomy Country Dashboard. Three core economic indicators—turnover, value added at factor cost, and employment—are analyzed, with turnover and value added additionally expressed on a per employee basis to enhance comparability. The results indicate a persistent and widening performance gap between Greece and the EU-27 average. Turnover per employee in the forestry sector declined by almost 45% between 2008 and 2023, while value added per employee decreased by more than 50%, contrasting sharply with strong upward trends observed at the EU level. Although total employment in the forestry sector of bioeconomy in Greece increased over the period, the sector's contribution to total bioeconomy employment remained limited, reaching

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only 1.43% in 2023, compared with approximately 2.6–3.1% in the EU-27. These outcomes reflect long-standing structural and institutional constraints, including fragmented forest ownership, low timber mobilization, outdated technologies, and limited innovation capacity, which have been exacerbated by external shocks such as the 2008 financial crisis and the COVID-19 pandemic. Comparative evidence from Northern European countries highlights the importance of coherent national strategies, technological upgrading, and coordinated policy frameworks. The study concludes that the development of a National Bioeconomy Strategy, supported by improved monitoring mechanisms and targeted investments, is essential for enhancing the contribution of the forest sector to sustainable regional development in Greece and for strengthening the competitiveness of the forest-based bioeconomy.

Zusammenfassung

Die forstbasierte Bioökonomie ist zu einer strategischen Priorität in der Europäischen Union (EU) geworden, jedoch bestehen weiterhin erhebliche Unterschiede zwischen den Mitgliedstaaten. Diese Studie bewertet die Leistung Griechenlands im Forstsektor der Bioökonomie im Zeitraum 2008–2023 anhand harmonisierter Daten aus dem Bioeconomy Country Dashboard der Europäischen Kommission. Es werden drei zentrale Wirtschaftsindikatoren analysiert: Umsatz, Wertschöpfung zu Faktorkosten und Beschäftigung, wobei Umsatz und Wertschöpfung zusätzlich pro Mitarbeiter angegeben werden, um die Vergleichbarkeit zu verbessern. Die Ergebnisse zeigen eine anhaltende und sich vergrößernde Leistungskluft zwischen Griechenland und dem Durchschnitt der EU-27. Der Umsatz pro Beschäftigten im Forstsektor ging zwischen 2008 und 2023 um fast 45 % zurück, während die Wertschöpfung pro Beschäftigten um mehr als 50 % sank, was in starkem Kontrast zu den starken Aufwärtstrends auf EU-Ebene steht. Obwohl die Gesamtbeschäftigung im Forstsektor der Bioökonomie in Griechenland im Laufe des Zeitraums gestiegen ist, blieb der Beitrag des Sektors zur Gesamtbeschäftigung in der Bioökonomie begrenzt und erreichte 2023 nur 1,43 %, verglichen mit etwa 2,6–3,1 % in der EU-27. Diese Ergebnisse spiegeln langjährige strukturelle und institutionelle Zwänge wider, darunter fragmentierte Waldbesitzverhältnisse, geringe Holznutzung, veraltete Technologien und begrenzte Innovationskapazitäten, die durch externe Schocks wie die Finanzkrise von 2008 und die COVID-19-Pandemie noch verschärft wurden. Vergleichende Erkenntnisse aus nord-europäischen Ländern unterstreichen die Bedeutung kohärenter nationaler Strategien, technologischer Modernisierung und koordinierter politischer Rahmenbedingungen. Die Studie kommt zu dem Schluss, dass die Entwicklung einer nationalen Bioökonomie-Strategie, unterstützt durch verbesserte Überwachungsmechanismen und gezielte Investitionen, von entscheidender Bedeutung ist, um den Beitrag des Forstsektors zur nachhaltigen regionalen Entwicklung in Griechenland zu erhöhen und die Wettbewerbsfähigkeit der forstbasierten Bioökonomie zu stärken.

1 Introduction

The roots of the bioeconomy lie in the biological sciences and biotechnology and are often traced back to early work on the economic implications of genomics. A widely cited early contribution is the article by Enriquez (1998) in *Science*, which demonstrated how advances in genomics could reshape various sectors and industrial production processes. While the term “bioeconomy” does not appear in that article, it is frequently considered an early articulation of the modern bioeconomy concept, emphasizing the transformative potential of biological sciences and biotechnology for industrial production and economic development. Subsequent literature has recognized these foundational ideas and has highlighted the shift from a biotechnology-centered vision to a broader, sustainability-oriented paradigm (Bugge *et al.*, 2016; Birner, 2017; Wei *et al.*, 2022). A recent trend highlights the need to connect the concept of bioeconomy more effectively with the concepts of sustainable development and the green economy (Birner, 2017). In recent years, an evolution to the concept of bioeconomy has been observed; it has become a broader, sustainability-oriented paradigm that encompasses the three sustainability pillars (economy, society and environment), leaving behind the initial narrow idea based almost solely on biotechnology (Brunori, 2013; Bugge *et al.*, 2016).

Bioeconomy is also linked to the concept of circular economy, since sustainable bioeconomy is considered the renewable segment of the latter. Circular economy is a relatively new concept that has emerged on the global policy agenda (Ghisellini *et al.*, 2016) and its main aim is to incorporate the spirit of sustainable development into the economic pillar (Corona *et al.*, 2019). While the bioeconomy focuses on the use of biological resources, the circular economy emphasizes the efficient use of resources. The green economy functions as an “umbrella” concept, encompassing elements of both the circular economy and the bioeconomy (D’Amato *et al.*, 2017). Recent studies have highlighted the intersection of circular economy and bioeconomy, and the concept of “circular bioeconomy” has been developed (Carus & Dammer, 2018; Philp & Winickoff, 2018; Venkata Mohan *et al.*, 2019; Falcone *et al.*, 2020). Stegmann *et al.* (2020) concluded that the concept of circular bioeconomy is not inherently sustainable, although it could contribute to improving the sustainability of the bioeconomy.

The bioeconomy, also known as the “biobased economy”, encompasses the production of biobased resources and their conversion into food, feed, bioenergy, and biobased materials. It is based on sustainable development through the application of biological and systemic knowledge and innovation to develop a sustainable economy (Lewandowski, 2018). In the European Union (EU), during the development of the bioeconomy concept, the term “knowledge-based” was added, resulting in the “knowledge-based bioeconomy”, which aligned with the EU’s innovation policy at the beginning of the millennium. During a meeting in Lisbon in 2000, the European Council committed itself to establishing “the most competitive and dynamic knowledge-based economy in the world” (European Union, 2000).

The European Union's initial Bioeconomy Strategy (European Commission, 2012) defined the bioeconomy as "the production of renewable biological resources and the conversion of these resources and waste streams into value-added products." According to the updated European Union Bioeconomy Strategy (European Commission, 2018), "The bioeconomy covers all sectors and systems based on biological resources (animals, plants, microorganisms, and biomass derivatives, including organic waste), their functions, and principles." According to the European Parliament (2013), a successful bioeconomy for Europe depends on the availability of food stocks, with sustainable management and sustainable sourcing. The development of the concept of bioeconomy in the European Union has been accompanied by increased funding, particularly in the EU's framework programs for research and technological development, and especially in the 8th framework program entitled "Horizon 2020" (European Commission, 2013). A circular bioeconomy strategy in the European Union will be a key tool for achieving the sustainable development goals (SDGs) of the 2030 Agenda for Sustainable Development and the Paris Climate Agreement, highlighting the role of forests as the most important land-based biological infrastructure on the European continent, supporting biodiversity and mitigating climate change (Hetemäki *et al.*, 2017). Moreover, the EU Bioeconomy Strategy could be a central policy for the EU Green Deal in the post-COVID-19 period, contributing to the sustainable development within the EU (Liobikienė & Miceikienė, 2023).

The definition of the forest bioeconomy remains an open and evolving issue at both the global and European Union levels. According to Rinn *et al.* (2022), the globally accepted concept of the bioeconomy includes the forestry sector, although the concept of forest bioeconomy has not been defined in a uniform manner. While all Member States of the EU agree that forestry constitutes an important component of the bioeconomy, the forest bioeconomy lacks a commonly accepted definition at the EU level, and its role and degree of integration differ significantly across Member States (Ludvig *et al.*, 2019). At the international level, the Food and Agriculture Organization of the United Nations (FAO) has proposed a definition for the wood-based bioeconomy as "a bioeconomy made of all biological resources derived from wood (including wood that does not come from forests and recycling of wood products)" (Bouillon, 2020: p. 6).

Within this conceptual diversity, the European Union recognizes the forest bioeconomy as a critical factor in achieving EU priorities, including the objectives of the European Green Deal and the SDGs of the 2030 Agenda for Sustainable Development (Jonsson *et al.*, 2021). Sustainable development is a central pillar of the bioeconomy in the European Union (European Commission, 2018), and its role has been recognized in the emerging EU bioeconomy policy framework as a "selling point" (Ramci-*lović-Suominen & Pülzl*, 2018). The forest bioeconomy contributes to sustainability by promoting the efficient and responsible use of natural resources, restoring and enhancing forest ecosystems. It also contributes to environmental protection, biodiversity conservation, and the enhancement of ecosystem services (European Com-

mission, 2018). Furthermore, it supports the circular use of resources, as the forestry sector is the second largest source of biomass in the EU, most of which comes from roundwood (Gurría *et al.*, 2022). The transition towards a forest-based bioeconomy requires robust information on forest structure and wood resource availability, highlighting the importance of harmonized datasets that enable comparable assessments across European countries (Pucher *et al.*, 2022).

Additionally, the forest bioeconomy plays a decisive role in mitigating climate change. Forests act as carbon sinks, contributing to carbon sequestration, while harvested wood products (HWPs) also store carbon. This mitigation potential is further enhanced by reductions in greenhouse gas (GHG) emissions, as carbon dioxide (CO₂) emissions drop significantly when wood products replace carbon-intensive materials such as concrete or steel (Jonsson *et al.*, 2021). Furthermore, forestry and the forest industry can play a fundamental role in providing bio-based substitutes for non-renewable resources (Ollikainen, 2014; Roos & Stendahl, 2015). Taken together, these characteristics show that the forest bioeconomy is a multifaceted and dynamic field that contributes to economic growth and the creation of new employment opportunities (Lewandowski, 2018).

The economic importance of the forest bioeconomy is also reflected in employment figures. In 2018, forestry and extended wood value chains employed 4.5 million people in the European Union (Robert *et al.*, 2020a). The forest-based sector is one of the pillars of the European bioeconomy, and research on the forest bioeconomy is an expanding field, characterized by diverse actors (Lovrić *et al.*, 2021). The updated European Bioeconomy Strategy identifies the forest sector as one of the principal supplier sectors that support achieving objectives such as job creation and employment through the green economy (Ludvig *et al.*, 2019). However, the role of forests and the forest sector is mostly neglected in the majority of EU bioeconomy strategies, except in Finland (Hetemäki *et al.*, 2017).

Significant disparities exist across EU Member States in the bioeconomy, particularly in the maturity of innovation solutions. Northern European countries, including the Scandinavian countries, Germany, Poland, and the Netherlands, lead in implementing such solutions. At the same time, Southern Europe generally lags behind, with notable exceptions such as bioplastics in France, lignin in Spain and wood-based materials in Slovenia (European Environment Agency, 2025). These differences reflect broader structural, institutional, and innovation-related gaps across Europe and provide important context for assessing the position of individual countries.

Greece is one of the countries where these disparities are particularly evident, especially in the forest-based segment of the bioeconomy. This is also reflected in the absence of a National Bioeconomy Strategy in Greece, although the country has adopted a National Circular Economy Strategy. In the European Union, eleven countries have dedicated bioeconomy strategies in 2025: Austria, Estonia, Finland, France, Ger-

many, Ireland, Italy, Latvia, the Netherlands, Portugal and Spain (Eliasson *et al.*, 2025). As indicated by Prieter *et al.* (2017), other European countries that have developed bioeconomy strategies include Norway and the Western Nordic countries (Iceland, Greenland, and the Faroe Islands), further widening the gap and highlighting disparities between Northern and Southern Europe in forestry and the forest-based bioeconomy.

The aim of this paper is to evaluate Greece's performance in the bioeconomy, with a particular focus on the forestry sector, during the period 2008–2023, using harmonized data from the European Commission, and to interpret the observed economic outcomes in light of the country's forest resource characteristics and structural conditions.

The paper is structured as follows: Section 2 presents the study area, the methodology used, the data source, and its processing, and explains the necessary terminology. Section 3 presents the results of the study, while Section 4 provides a discussion of the findings and compares them with other studies. Finally, section 5 summarizes the study's conclusions, based on the results and discussion.

2 Materials and Methods

2.1 Description of study area: Forest land, ownership structure and forest resources in Greece

Greece is characterized by a predominantly Mediterranean forest landscape with strong spatial heterogeneity and pronounced ecological constraints. According to official data from the Ministry of Environment and Energy of Greece and the Greek National Forest Strategy (2018–2038), forests cover approximately 30% of the national territory (around 3.8–3.9 million hectares). When other wooded land, such as shrublands and grazed forest formations, is included, forest-related land accounts for nearly 49% of the country's surface (Ministry of Environment and Energy - Greece, 2018). The most recent Eurostat data (December 2024) confirm that forests account for 29.63% of the total land area of Greece (European Commission-Eurostat, 2024). Recent pan-European forest structure products also combine National Forest Inventory information with remote sensing and gap-filling approaches, providing spatially explicit indicators (*e.g.*, volume and biomass) that have been shown to be consistent with published national statistics and are useful for contextualizing country-level analyses (Pucher *et al.*, 2022).

Forest ownership in Greece is largely public, with approximately three-quarters of forest land under state ownership, while municipal, church owned and private forests represent much smaller shares (Spanos *et al.*, 2021). This ownership structure,

combined with fragmented management responsibilities, has long influenced forest governance and resource mobilization.

Greek forests are dominated by coniferous species (approximately 58% of high forests), mainly pine species (*Pinus halepensis*, *Pinus brutia*, *Pinus nigra*) and firs (*Abies* sp.), while broadleaved species account for about 42%, dominated by oak (*Quercus* sp.), beech (*Fagus* sp.), and chestnut (*Castanea* sp.) (Spanos *et al.*, 2021). Forests in Greece are primarily located in mountainous and semi-mountainous areas and often fulfil protective and environmental functions rather than intensive wood production. A distinctive feature of the Greek landscape is that a substantial share of forested areas is situated on steep mountainous terrain and slopes (Zagas *et al.*, 2001), which makes harvesting operations technically demanding and costly (Tsioras & Liamas, 2015). In line with this, the average growing stock of Greek forests has been reported to be about 62 m³/ha, based on estimates from the First National Forest Inventory (Ministry of Agriculture, 1992, as cited in Spanos *et al.*, 2021), while approximately 70% of harvested wood is used as firewood, reflecting the generally low intensity of industrial roundwood production (Spanos *et al.*, 2021). As a result, timber productivity remains relatively low compared to northern and central European countries.

Regarding Greece's forested areas and other wooded land, the total growing stock of living trees is estimated at approximately 193 million cubic meters. Based on the reported forest area (3.8–3.9 million ha), this corresponds to an approximate mean growing stock of about 49–51 m³/ha, providing an indicative order-of-magnitude estimate at the national scale. Of this volume, around 83 million cubic meters correspond to coniferous species, while the remaining share consists of broadleaved trees, excluding shrub volume (FAO, 2013). However, only a limited share is economically utilized (Tsiaras *et al.*, 2020; Koulelis *et al.*, 2023). According to the available Eurostat roundwood removals data, harvesting intensity in Greece remains low, corresponding to approximately 0.30–0.31 m³/ha/year in 2022 and 0.29–0.30 m³/ha/year in 2023 (European Commission-Eurostat, 2025). These characteristics provide essential context for interpreting the economic performance of the forestry sector within the Greek bioeconomy.

2.2 Data sources, indicators and analytical framework

For the purposes of this paper, data from the official website of the European Union were used, specifically from the European Commission's online data platform "The bioeconomy in different countries" (European Commission, 2025). The bioeconomy sectors in the European Union are as follows (Source: European Commission, 2025):

- 1) Agriculture,
- 2) Bio-based chemicals, pharmaceuticals, plastics, and rubber (excluding biofuels),
- 3) Bio-based electricity,

- 4) Bio-based textiles,
- 5) Fishing and Aquaculture,
- 6) Food, beverage and tobacco,
- 7) Forestry,
- 8) Liquid biofuels,
- 9) Paper,
- 10) Wood products and furniture.

The data cover the period 2008–2023, and the selected indicators for this study are turnover, value added at factor costs, and employment for all bioeconomy sectors and for the sector “Forestry” of the bioeconomy. These three indicators were selected because they are the core economic metrics used by the European Commission to monitor the performance and growth dynamics of the bioeconomy. Although the bioeconomy comprises a wide range of sectors, this study focuses on the forestry sector, as it represents the core land-based component of the bioeconomy and is directly linked to forest resources, forest management, and wood supply.

In this paper, the term “forestry sector of the bioeconomy” refers specifically to economic activities classified under NACE A02 in Eurostat data, representing the sector “Forestry” of the bioeconomy. The term “forest-based bioeconomy” is used in a broader conceptual sense, encompassing forestry and forest-based value chains, while the term “forest sector” is employed at the policy level to describe the wider system of forestry-related activities, governance structures, and strategic frameworks.

Turnover is used as an indicator of market size in the EU bioeconomy strategy and represents the total value of sales generated by a given sector, including intermediate sales along the bioeconomy value chain, which may lead to limited double counting. Value added at factor cost corresponds to gross operating income after adjustment for operating subsidies and indirect taxes, excluding depreciation. Employment refers to the number of persons aged 15 years and over employed in the sector, including full-time and part-time workers, persons temporarily absent from work, and unpaid family workers, in line with Eurostat definitions.

Turnover and value added data are originally reported by the European Commission based on Eurostat national accounts. In order to improve comparability across countries with different economic and structural conditions, the analysis additionally normalizes turnover and value added by employment, presenting these indicators on a per employee basis. This approach allows for a more meaningful comparison of economic performance within the forestry sector of the bioeconomy across countries and over time.

The following section presents the evolution of the relevant indicators for the period 2008–2023 in Greece relating to the bioeconomy in the forestry sector. For each indicator, average values were used, and the change between the initial value in the base year (2008) and the final value in the most recent year for which data were available (2023) was calculated. The period of analysis (2008–2023) allows capturing long-term

structural trends, as well as more recent post-pandemic developments and policy dynamics affecting the forestry sector of the bioeconomy in Greece.

3 Results

Based on the data sources and indicators described in the Materials and Methods section, the Results section presents the empirical results on the evolution of the forestry sector within the Greek bioeconomy over the period 2008–2023. Table 1 presents the evolution of the bioeconomy in the forestry sector in Greece over this period. The data are derived from the European Commission's Bioeconomy Country Dashboard (European Commission, 2025) and include the following indicators:

- (i) turnover,
- (ii) value added at factor cost, and
- (iii) employment.

In line with the methodological approach described above, turnover and value added are additionally presented on a per employee basis in the tables, in order to enhance comparability over time. All monetary values are expressed in euros; decimal points are used as decimal separators, and commas are used as thousand separators.

Table 1: Evolution of the bioeconomy in the sector "Forestry" in Greece over the period 2008–2023.

Tabelle 1: Entwicklung der Bioökonomie im Sektor „Forstwirtschaft“ in Griechenland im Zeitraum 2008–2023.

Year	Turnover (€ / employee)	Added Value (€ / employee)	Employment (number of employees)
2008	14,000.00	10,909.09	5,500
2009	11,785.71	9,821.43	5,600
2010	12,264.15	9,245.28	5,300
2011	12,333.33	10,000.00	6,000
2012	15,800.00	12,800.00	5,000
2013	19,782.61	16,086.96	4,600
2014	12,500.00	9,117.65	6,800
2015	11,724.14	9,931.03	7,200
2016	10,266.67	8,800.00	7,500
2017	9,487.18	7,820.51	7,800
2018	8,314.61	6,741.57	8,900
2019	7,789.47	6,421.05	9,500
2020	7,662.34	6,103.90	7,700
2021	6,741.57	5,168.54	8,900
2022	8,125.00	5,625.00	9,600
2023	7,722.77	5,346.53	10,100

The average values for the period 2008–2023 were as follows: turnover in total €74.75 million, turnover per employee €10,305.90, added value in total €59.06 million, added value per employee €8,143.00, and average employment of 7,253 employees.

Compared to the base year (2008), turnover per employee in the forestry sector of the bioeconomy in Greece decreased by almost 45% (–44.84%) in 2023, while total turnover over the same period showed a marginal increase of 1.30%.

The added value per employee decreased by more than 50% (–50.99%), while the added value in total for the same period decreased by 10%. Finally, employment increased by almost 84% (83.64%), with the number of employees increasing by approximately 4,500 between 2008 and 2023.

Figure 1 shows the evolution of turnover per employee (€ per employee) in the sector “Forestry” of the bioeconomy in Greece over the period 2008–2023, compared with the corresponding average for the European Union (EU-27).



Figure 1: Evolution of turnover per employee (€ per employee) in the sector “Forestry” of the bioeconomy in Greece and the European Union (EU-27) over the period 2008–2023.

Abbildung 1: Entwicklung des Umsatzes pro Mitarbeiter (€ pro Mitarbeiter) im Bereich „Forstwirtschaft“ der Bioökonomie in Griechenland und der Europäischen Union (EU-27) im Zeitraum 2008–2023.

The turnover per employee in the sector “Forestry” of the bioeconomy in Greece lags significantly behind the EU-27 average over the period 2008–2023, with the gap widening further in recent post-COVID years, particularly after 2020. In 2008, the difference amounted to approximately €64,500 per employee, while by 2023 it had increased substantially to more than €123,000 per employee. The average turnover per employee for the period 2008–2023 in Greece was €10,306, while in the European Union was €94,206, approximately nine times higher. The change in turnover per employee between 2008 and 2023 shows a decrease of almost 45% (-44.84%) for Greece, as also reported in Table 1, whereas the corresponding figure for the European Union increased by almost 67% (66.9%).

Figure 2 shows the evolution of added value per employee (€ per employee) in the sector “Forestry” of the bioeconomy in Greece over the period 2008–2023, compared with the corresponding average for the European Union (EU-27).

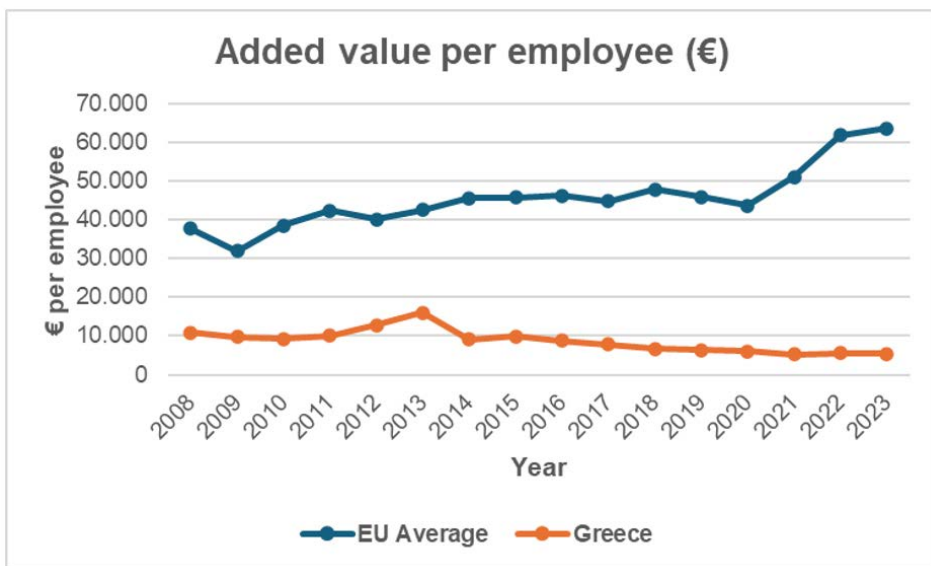


Figure 2: Evolution of added value per employee (€ per employee) in the sector “Forestry” of the bioeconomy in Greece and the European Union (EU-27) over the period 2008–2023.

Abbildung 2: Entwicklung der Wertschöpfung pro Beschäftigten (in Euro pro Beschäftigten) im Bereich „Forstwirtschaft“ der Bioökonomie in Griechenland und der Europäischen Union (EU-27) im Zeitraum 2008–2023.

The added value per employee in the sector “Forestry” of the bioeconomy in Greece remains consistently lower than the EU-27 average throughout the period 2008–2023, with the gap widening substantially over time. In 2008, the difference amounted to approximately €26,900 per employee, while by 2023 it had increased by almost €58,500 per employee.

Over the entire period examined, the average added value per employee in Greece was €8,143, compared to €46,100 in the European Union, indicating a more than five-fold difference in labor productivity between Greece and the EU average. While the EU-27 shows a clear upward trend in added value per employee, particularly after 2020, Greece exhibits a pronounced downward trajectory after 2013, with only minor fluctuations thereafter.

Between 2008 and 2023, added value per employee in Greece decreased by more than 50% (-50.99%), whereas in the European Union it increased by approximately 69%, highlighting a growing divergence in value creation capacity within the sector “Forestry” of the bioeconomy.

Figure 3 shows the evolution of employment in the sector “Forestry” of the bioeconomy as a share of total employment in all bioeconomy sectors in Greece and the European Union (EU-27) over the period 2008–2023.

Employment in the sector “Forestry” represents a relatively small but gradually increasing share of total bioeconomy employment in Greece over the period 2008–2023. Following a decline during the years 2009–2013, which coincides with the domestic economic crisis and the onset of the Memorandum period, the employment share exhibits a steady upward trend from 2014 onwards, reaching 1.43% in 2023. The temporary decline observed in 2020 reflects the broader economic effects of the COVID-19 pandemic on employment across the Greek economy. In contrast, employment in the sector “Forestry” accounts for a consistently higher and remarkably stable share of total bioeconomy employment in the European Union. Throughout the period examined, the EU-27 maintains values ranging between approximately 2.6% and 3.1%, highlighting a persistent structural gap between Greece and the EU average in terms of the employment contribution of forestry within the bioeconomy.

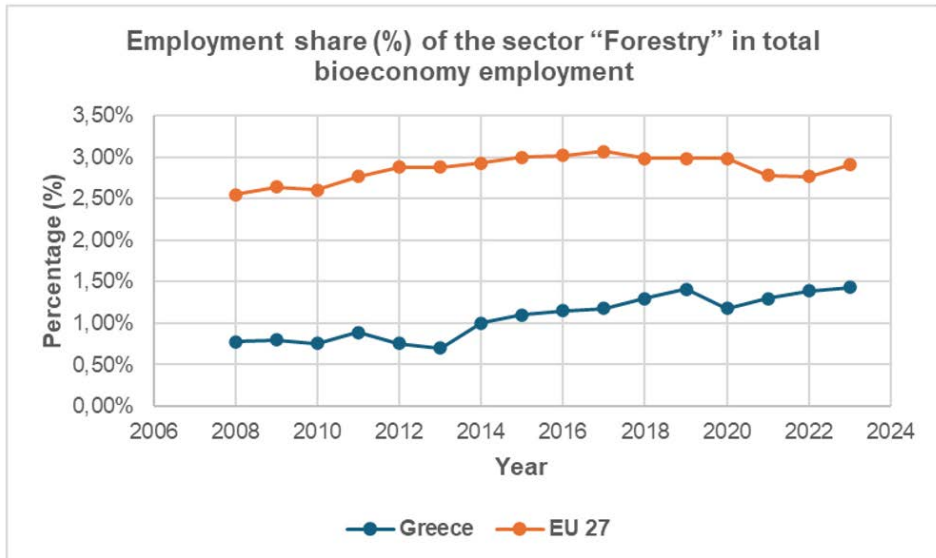


Figure 3: Evolution of the employment share (%) of the sector “Forestry” in total bioeconomy employment in Greece and the European Union (EU-27), 2008–2023.

Abbildung 3: Entwicklung des Beschäftigungsanteils (%) des Sektors „Forstwirtschaft“ an der Gesamtbeschäftigung in der Bioökonomie in Griechenland und der Europäischen Union (EU-27), 2008–2023.

4 Discussion

4.1 Interpretation of Greece’s performance

Greece has made some progress in recent years in the field of the bioeconomy, but still lags significantly behind the European average. The recent COVID-19 pandemic has had a significant impact on its performance, placing Greece among the lowest-performing EU Member States. This phenomenon can be explained by the fact that major external shocks—such as the 2008 global financial crisis and the COVID-19 pandemic—tend to disproportionately affect weaker economies, limiting their capacity for rapid recovery (Oravský *et al.*, 2020). The observed post-2014 recovery in Greece, although modest in magnitude, is in line with earlier findings for the broader forestry-related bioeconomy, which indicate a gradual stabilization of employment following the deep contraction of the crisis years (Maris & Flouros, 2022). However, the substantially lower employment share of the core forestry sector suggests that structural constraints continue to limit its contribution to bioeconomy employment in Greece, despite signs of partial recovery.

Supporting this interpretation, Greece is classified among the weaker EU economies (Oravský *et al.*, 2020) and ranks last among EU Member States in indicators closely related to the forest bioeconomy, such as wood supply, the use of forest products, and employment in the forest-based sector (Tsiaras & Andreopoulou, 2020). In this context, harmonized forest structure information at the European scale can provide an independent and spatially explicit benchmark for key variables such as growing stock and biomass, supporting the interpretation of cross-country differences (Pucher *et al.*, 2022).

4.2 Explaining Greece's lagging position

In Greece, broader institutional and structural factors significantly constrain the development of a robust forest bioeconomy. Our findings are consistent with previous research highlighting that the forest-based bioeconomy in Southern Europe faces complex obstacles, the most prominent being the fragmentation of forest ownership, which hinders timber mobilization and contributes to very low utilization rates of forest resources (Martinez de Arano *et al.*, 2018). In addition, Southern European countries face structural constraints related to low investment in innovation and outdated processing technologies (Martinez de Arano *et al.*, 2018). These limitations, also observed in Greece, further reduce the capacity of the forest sector to generate higher added value. A stronger focus on non-wood forest products (NWFPs) could have a positive influence on employment, creation of added values and the contribution of forestry to the national bioeconomy as shown by Posavec *et al.* (2021) in their assessment of the economic footprint of NWFPs in Croatia.

4.3 Comparison with EU and successful cases

Northern European countries provide several best practices in the field of forest-based bioeconomy, offering valuable insights for less developed countries, including those in Southern Europe. Nordic countries demonstrate long-term strategies, stakeholder engagement, and coherent policy instruments that promote innovative solutions across the entire forest value chain (Hetemäki *et al.*, 2017).

Finland stands out as a leading country in forest bioeconomy, with Finnish forest-based companies often seeing themselves as forerunners of a sustainable circular bioeconomy, emphasizing the "reasonable use of wood" (Näyhä, 2019). Moreover, the Leading Forest Firms of the country adopted noteworthy digital solutions such as online wood trade, drone helicopters for forest inventory, and virtual reality. These solutions have promoted the versatile use of renewable wood biomass, improved resource efficiency, expanded the potential of renewable raw materials and product value, and ultimately made forest management easier (Watanabe *et al.*, 2018).

Beyond Finland, countries such as Germany and Spain have achieved strong results in the forest-based bioeconomy, particularly in areas linked to sustainability principles, such as the sustainability of the biomass resource base, production processes, and consumption patterns (Barañano *et al.*, 2022). These examples underline that high performance in the forest bioeconomy is closely associated with national strategies that incorporate good governance, value chain coordination, and investments in innovation.

However, despite the strong performance of these countries, implementation challenges remain even among leaders in the forest bioeconomy. Empirical research on how small and medium-sized enterprises (SMEs) adopt sustainability-related circular business models is only just emerging in Finland (D'Amato *et al.*, 2020).

4.4 Structural and institutional disparities in Southern Europe

Structural and institutional weaknesses are well-documented barriers to the development of a competitive forest-based bioeconomy in Southern and Southeastern Europe. A study in Croatia, Serbia and North Macedonia concluded that the absence of advanced technologies in the wood-processing sector is one of the main reasons why wood production in these countries struggles to achieve higher added value (Lovrić *et al.*, 2021). The same authors also underline a lack of human capacities necessary to support the growth and further integration of bioeconomy sectors (Lovrić *et al.*, 2021). These barriers are also evident in Greece, where the use of obsolete equipment in the wood industry and the shortage of skilled workers in forest operations are consistently identified as key obstacles in the forest sector.

A study in Italy developed a set of simple, practical, and easy-to-use indicators to assess the performance of the forest-wood chain following the principles of circular bioeconomy within the framework of the implementation of the Italian National Sustainable Development Strategy in the forest-based sector (Paletto *et al.*, 2021). Greece could similarly benefit from developing a dedicated set of indicators to measure and assess the forest-based circular bioeconomy, following the Italian example, which would help monitor progress on bioeconomy strategies and evaluate key dimensions such as productivity, performance, and efficiency. In Croatia, another study evaluated the contribution of non-wood forest products (mushrooms, aromatic and medical plants, berries and other fruits) to the bioeconomy. The authors concluded that the average prices of non-wood forest products at both the local and international market levels are higher than expected (Posavec *et al.*, 2021).

These examples illustrate how targeted actions can enhance the performance of the forest sector, but specific policy strategies are generally absent in many Southern European countries. As highlighted by Winkel (2017), recognizing regional differen-

ces in Europe is crucial for the development of the forest-based bioeconomy; therefore, a multi-level policy approach is needed, in which the EU defines the concept and basic rules for forest-based bioeconomy markets, while regional and national levels adapt these to local conditions.

4.5 Implications for Greece

A coherent, evidence-based policy framework is essential to address the structural gaps identified in Greece's forest-based bioeconomy. Robert *et al.* (2020b) proposed a bioeconomy monitoring framework for the European Union, using an integrative and collaborative approach that incorporates the three sustainability pillars (economy, society, and the environment). Such a framework may help identify and track disparities between regions or countries in the development of the bioeconomy and provide sustainable solutions to mitigate them. Applying a similar approach would be particularly valuable for Greece, where monitoring mechanisms and performance indicators remain underdeveloped. From a monitoring perspective, integrating harmonized forest structure datasets into national and EU-level frameworks could improve evidence-based policy design and support strategic planning for the forest-based bioeconomy (Pucher *et al.*, 2022).

The impact of global economic events on the economy is even more evident in Greece's forestry sector, which is characterized by an inadequate political and institutional framework, limited investment in innovation, and slow adaptation to new bioeconomy standards. These weaknesses hinder the sector's ability to respond effectively to crises and limit its capacity to generate higher added value. A study that evaluated the National Forest Strategy (NFS) of Greece (Ministry of Environment and Energy - Greece, 2018) also highlights long-standing structural weaknesses in the country's forest sector, including the very low economic contribution of forestry to the country's Gross Domestic Product-GDP (only 0.05%), chronic trade deficit, and significant reductions in funding caused by the economic crisis (Tsiaras *et al.*, 2020). At the same time, the NFS emphasizes the model of Mediterranean forestry and sustainable forest management as key tools to promote regional development, indicating that Greece has meaningful prospects for improvement that could support a transition toward a stronger forest-based bioeconomy and enhance the contribution of forestry to the national economy.

A recent assessment of the Greek forest sector further supports these findings, revealing a persistent decline in domestic wood production across all major product categories and a substantial increase in imports, which intensified after the economic crisis (Koulelis *et al.*, 2023). The authors also conclude that Greece requires a new legal framework to ensure the long-term sustainability and productivity of forest resources, emphasizing the implementation of sustainable forest management. These insights

underline the urgent need for coordinated policy interventions to strengthen the competitiveness and sustainability of the forest-based bioeconomy in Greece. Greece should therefore make use of the existing institutional framework established by the National Strategy for the Circular Economy and the National Forest Strategy, aiming to draft a National Strategy for the Bioeconomy in the coming years, drawing on best practices from European Union member states that are performing well in the bioeconomy sector, such as Finland, and Germany, which have a National Strategy for the Bioeconomy. The existence of a specific institutional framework would enable better policy coordination, financing, and investment attraction in the forestry sector. The establishment of a National Bioeconomy Strategy would help Greece integrate sustainability, innovation, and socio-economic objectives in line with EU policy frameworks.

5 Conclusions

The findings of this study show that Greece underperforms in key economic dimensions of the forestry sector of the bioeconomy, particularly in turnover and value added, while performing relatively better in employment. However, this remains substantially below the EU average. Despite some positive developments, persistent disparities with the EU average remain evident throughout the period 2008–2023. These outcomes reflect long-standing structural constraints, including low levels of innovation, technological obsolescence, limited mobilization of forest resources and broader institutional weaknesses that hinder the competitiveness of the sector.

Addressing these challenges requires coherent policy actions. The development of a National Bioeconomy Strategy would provide Greece with an integrated framework that aligns sustainability, innovation and socio-economic objectives with EU policy priorities. The establishment of monitoring mechanisms is also important, drawing on existing frameworks proposed in recent literature, to ensure systematic evaluation of progress. Strengthening cross-sectoral integration, investing in human capital and technological modernization, and learning from successful Nordic examples could significantly enhance the country's capacity to transition toward a sustainable, competitive forest-based bioeconomy.

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