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The impact of space development structure on the level of ecological footprint - Shift share analysis for European Union countries

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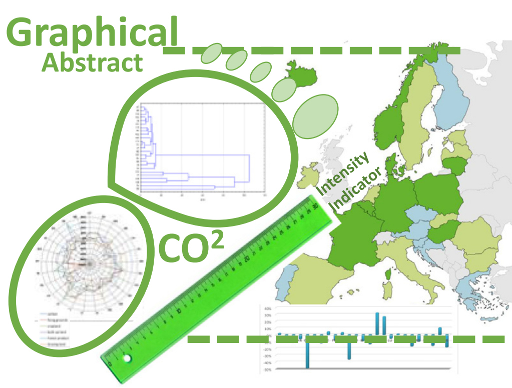
HIGHLIGHTS

- The land use structure has an impact on the level of the ecological footprint.
- Based on data from 2009 to 2019 EU countries were tested using the share analysis method.
- The greatest changes in the demand for natural resources have been observed in Latvia and Lithuania.
- The largest decrease of the ecological footprint was observed in Cyprus.
- The biggest changes took place in fisheries and the smallest in arable land.

GRAPHICAL ABSTRACT



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ABSTRACT

The impact of the space development structure on the level of the ecological footprint is an important element of the sustainable development policy, determining not only its directions, but also indicating the manner of respecting environmental principles. The aim of the research is to assess the impact of the spatial development structure on the ecological footprint level. The considerations are based on the assumption that the spatial development structure is a determinant of the ecological footprint level. The study used the shift share analysis method. Selected European countries were the subject of the research. The research period covered the years 2009–2019. The spatial differentiation of the GDP level and the ecological footprint were compared. For each country, the components of structural changes were determined and their changes over time were assessed. The study positively verified the main hypothesis and the auxiliary hypothesis. The ecological footprint decreased in the analyzed period. This phenomenon was not evenly distributed in European countries. Regions with a higher level of changes in the phenomenon than the EU average can be distinguished. The greatest changes in the demand for biosphere' natural resources in hectares of land and sea were recorded in Latvia and Lithuania. In contrast, the largest decrease in the size of the ecological footprint was observed in Cyprus. Differentiation of changes was visible within the individual components making up the ecological footprint in

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the analyzed period. The biggest changes took place within the fishing grounds. The smallest changes were recorded for cropland. This paper is expected to provide policy makers with a set of policy proposals to achieve sustainable environmental and economic development.

1. Introduction

The idea of the ecological footprint is part of the activities for the resource-efficient European strategy implementation, which is currently a key community policy. The Ecological Footprint is a resource accounting tool used to answer to a question: How much of the planet' biological capacity is required by a given human activity or population? It is a measure of the need for the biosphere' natural resources in hectares of land and sea, which are needed to produce the products and services, but also to absorb waste. In other words, it is an attempt to estimate the needs of humanity against our planet' productivity. It is calculated in global hectares per capita (Global Footprint Network, 2021).

The ecological footprint can be calculated individually for each person or for a group of people - organization, society, nation, as well as for the producer, type of production or a specific product or service. All biological materials consumed and all annual emissions of carbon dioxide produced are taken into account. The ecological footprint shows how much space we occupy on Earth with our everyday needs - transport, food, energy consumption, etc. Thanks to this, can see what impact the lifestyle of each of us has on the Earth.

Even 50 years ago the planet was able to meet our needs - in 1970, Ecological Debt Day fell two days before the New Year. Since then, the population has more than doubled, the world economy more than 4 times. In 2021, the Ecological Debt Day fell on July 29, which means that we lived for 156 days on ecological credit, consuming the resources of future generations. Less than 7 months was enough to use up the Earth's resources, which our planet needs a whole year to restore. This means that we already need 1.75 planet to satisfy our appetite. Although the record holders in the use of the planet's resources and greenhouse gas emissions are the inhabitants of Qatar and Luxembourg (for them the debt day is already in February), and the residents of the USA or Canada are chasing them (for them the debt day is in mid-March), the EU member states also have no reasons to complacency. If everyone on Earth wanted to live like the average EU citizen, we would need 2.8 planets to meet our needs. In 2020 - due to the coronavirus pandemic - this date was later than a year earlier (July 29, like in 2021), namely on August 22. COVID-19 has caused humanity's ecological footprint to shrink. The coronavirus-induced economic closures have reduced the global ecological footprint by nearly 10 %. This postponed this bleak date by more than three weeks compared to last year. Even so, we still use as much ecological resources as if we were living on 1.6 Earths. However, these data have been averaged across all mankind. Each country reaches the limit of the Earth's annual resources at a different time. For example, Poland started incurring debt in 2021 already on May 14, when Kyrgyzstan only started on December 26 (Earth Overshoot Day, 2021).

EU countries consume as much as one fifth of the Earth's resources, despite the fact that they constitute only 7 % of the global population. As a result, the resources of the Earth are no longer sufficient for us, and the climate has changed so severely that it is increasingly threatening our species. Living on credit means emitting more gases than the Earth can absorb, progressive deforestation, overfishing, soil erosion and biodiversity loss. The dominant component of our ecological footprint (60 %) is carbon dioxide, which comes from burning fossil fuels (Living Planet Report, 2018).

Taking into account the importance of the topic, the aim of the article is to assess the changes that have occurred in the size and structure of the ecological footprint in the context of space development. The following hypothesis was adopted: the size of the ecological footprint is positively correlated with the level of GDP. Additionally, it was assumed that along with the increase in GDP, the level of industrialization of a given country increases, which translates into an increase in the ecological footprint. The study used the shift share analysis method. It allows for the decomposition of changes in the total area shift (TS – total shift) in relation to another reference area for a specific variable into three additive components: national share, sector structure and region share.

Our research is relevant both for theory and practice. We show how, i.e., what methods can be used to study the impact of spatial development on the level of ecological footprint enriches. Moreover, we positively verified the assumption that the way of spatial development is a determinant of the level of the ecological footprint. The practical dimension of our research is reflected in the discussion of the obtained results. The empirical significance of the use of comparative analysis was based on the time factor and the research subject, i.e., the EU countries.

This research logic determined the structure of the article. The first step of the research was a literature review, where the main focus was to present the essence of the ecological footprint, the method of its calculation and the relationship of the ecological footprint with various economic concepts falling within the scope of sustainable development. The Methodology section (Section 3) describes the essence of the shift share analysis. In Section 4, the ratio of green areas to built-up areas (intensity index) in the EU countries was calculated based on data from 2009, 2014 and 2019. Then, the Ward method was used to look for similarities between countries with regard to the ecological footprint and the intensity index in the analyzed period. It also shows the structure of changes in the ecological footprint and its relationship with the structural and regional effect. Section 5 presents general conclusions, limitations of our research and indicates the directions of further research in this area.

2. Literature review

In principle, the ecological footprint is considered through the prism of assessing the environmental degradation degree as an indicator of natural resources consumption or as a cost of human life. Nowadays, the concept of ecological footprint functions in a scientific but also in practical space as an integral element of spatial planning, building environmental policies of cities, regions, or countries, also more and more often as an element of ecological education. The very concept of the ecological footprint as a useful concept in the field of shaping environmental policy and human functioning in the natural environment has been popularized by Rees and Wackernagel (1996). They stated that satisfying the consumption of the human population at a high level exceeds the capabilities of the planet. They created the theoretical foundations and formulas that quantify the consumption and production capacity (primary production) of individual areas of the Earth. A pioneering publication on this topic (at the academic level) was published in 1992 (Rees, 1992). The paper shows the concepts of human carrying capacity and natural capital to argue that prevailing economic assumptions regarding urbanization and the sustainability of cities must be revised in light of global ecological change. The Ecological Footprint has been interpreted here (Rees, 1992) as an area of productive land and sea ecosystems, necessary for the production of resources used by humanity and for the assimilation of waste generated thereby, yet these areas are closely interrelated.

The ecological footprint is one of the relatively new measures allowing the assessment of human pressure on the environment by the volume of consumption of goods and services. The ecological footprint considers many variables, and the calculations can become complicated. To calculate the ecological footprint of a nation, may would use the equation by Galli et al. (2007), Solarin et al. (2019). A broad coverage of the different methodological options for the environmental footprint calculations is presented in Wiedmann and Barrett (2010). They noticed that none of the methods listed can address all important issues at once. The value of the ecological footprint determines the surface of the biologically productive area that is necessary to meet the living needs of the human population, including lifestyle. But it does not take into account the problem of environmental conflicts, which is indicated, for example, in the studies of Pacheco and Sanches Fernandes (2016), Pacheco et al. (2014).

In many respects, the ecological footprint is a tool used not only in studying ecological phenomena and measuring resource consumption but also as an instrument for creating analytical concepts. This approach is used in cyclical studies of the Living Planet Report (2018).

The strategic approach to building the structure of environmental pressure was included in one of the first approaches to sustainable development in the document of "Our Common Future" (World Commission on Environment and Development, 1987). The ecological footprint as a non-synthetic indicator was presented by Wackernagel and Rees (1994). Thanks to their approach, it is now possible to use the ecological footprint as part of the structure of sustainable development, because the possibility of creating ecological footprint calculators has been enabled. Over time, efforts were made to formalize the parameterization of the ecological footprint. To this end, a proposal was made from a European Commission project (European Union, 2013) whose task was to create a methodology for determining the ecological footprint of products. It was then stated that it was necessary to develop a more extensive, harmonized methodology for assessing the environmental impact of business, covering all environmental aspects, including greenhouse gas emissions (carbon footprint). The studies were based on the existing approaches of the life cycle assessment (LCA) and international standards; also, additional methodological specifications necessary to achieve greater consistency, comparability and accuracy of results were introduced. As a result, in 2012, based on the European Commission, the first development of the methodology for the parameterization of the environmental footprint was developed, including the methods for determining the ecological footprint of products (PEF) and the ecological footprint of an organization (OEF). These two methods have given several vital improvements over other methods used to date, e.g., a clear identification of potential environmental impact categories that need to be investigated for a comprehensive life cycle assessment, a requirement to quantify data quality, setting minimum data quality requirements, clearer technical instructions regarding the treatment of specific critical issues (European Union, 2013).

The ecological footprint semantics are often discussed in the context of sustainable development. This approach to the issue of the ecological footprint can be found in the works of Syrovátka (2020), Wiedmann and Barrett (2010), Fiala (2008), Van den Bergh and Verbruggen (1999). This directs the understanding of the concept of the ecological footprint as a necessary tool in assessing the degree of balancing the consumption of natural resources with the pace of their renewal. In addition, in the context of sustainable development, the concept of ecological footprint occurs in relation to other concepts such as: biocapitalization (De Pascale et al., 2021; Hu et al., 2015; Toderoiu, 2010; Wackernagel et al., 1997), decarbonization (Sinha et al., 2022; Hammond et al., 2019; Pulselli et al., 2019; Mazzanti and Rizzo, 2017; Szopik-Depczyńska et al., 2017; Alderson et al., 2012), carbon footprint (Doğan et al., 2022; Jiang et al., 2022; Jóhannesson et al., 2020; Bello et al., 2018; Mancini et al., 2015; Galli et al., 2011), water footprint (Feng and Zhao, 2020; Bello et al., 2018; Galli et al., 2011), lean production (Taddeo et al., 2019; Aldieri et al., 2019; Lenzo et al., 2017). It should be emphasized that the concept of ecological footprint is not the same as the cited concepts. It is often a reference for these concepts to look for different correlations. It should also be noted that, against this background, the ecological footprint is included in the group of social indicators used to measure the quality of life of the community in the light of contemporary environmental requirements. This approach can be seen in the authors' studies: Jaros (2014), Fang et al. (2014), Ioppolo et al. (2012), Venetoulis and Talberth (2008), Hoekstra (2009).

Research on changes taking place in the natural environment requires an interdisciplinary approach. The phenomenon of environmental degradation should be considered primarily as a result of human economic activity, who constantly exploits the environment. This complexity of the phenomenon was presented in the theoretical environmental concept of the Kuznets curve (EKC). In their research, Kuznets (Kuznets, 1955) discussed the relationship between wealth and income inequality in society. His research shows that as a country grows, social inequalities rise to a certain point and then decline. The graphical representation of this relationship is called a bell curve and resembles an inverted letter "U". Grossman and Krueger (1992), authors of the environmental Kuznets curve hypothesis, described a similar relationship in their science publication. They found that environmental degradation increases in the early stages of economic growth. However, this trend changes after reaching a certain level of income, the so-called Income Turning Point (ITP) (Emerson and Pendleton, 2004). After exceeding this point, the ability to incur costs for environmental protection increases, and further economic development does not cause deterioration of the environment. Explaining this more broadly, intensive agricultural development and industrialization imply the consumption of natural resources at a faster pace than their renewal, as well as a rapid increase in the amount of waste. At a higher level of economic development, appropriate structural changes in the development of production and services, which use knowledge about the natural environment, combined with increased environmental awareness and enforcement of environmental protection regulations, more friendly technologies and increasing environmental protection expenditure, gradually reduce environmental degradation (Panayotou, 1993). Thurow (1999) notes that only economic development and gradual improvement in living standards make people more concerned with resource conservation. With a low standard of living, the main concern is to meet the basic needs of life. With a higher standard of living, when livelihoods are provided and there is no need to worry about survival, a better environment becomes more important and takes on some value as it will have an impact on the standard of living in the future.

It is noted in the literature (Stern et al., 1996; Ekins, 1997) that the Kuznets curve shows the relationship between the level of GDP and the level of environmental degradation, but does not explain its essence. Explaining its essence requires taking into account many factors determining the amount of GDP and the level of environmental pollution. Panayotou (2003) believes that the analysis of dependence in general requires taking into account three independent factors: the intensity of management measured by the level of GDP, the sectoral structure of GDP, with particular emphasis on the share of services, the need for environmental protection.

The literature feeds a fairly large collection of empirical works that validate the EKC hypothesis from various perspectives. Studies conducted for the economies of individual countries, such as China (Jalil and Feridun, 2011), Vietnam (Tang and Tan, 2015), India (Tiwari et al., 2013), Turkey (Sharif et al., 2020), Iceland (Baek, 2015) confirmed the correctness of the EKC assumptions. Panel studies were also carried out, which included, inter alia, high income countries (Al-Mulali et al., 2015), developing and developed countries (Zaman et al., 2016), countries of Central and Eastern Europe (Atici, 2009). However, the results of empirical research not always confirmed the correctness of the EKC. Destek and Sinha (2020) used EFP to study EKC for 24 OECD countries. The EKC hypothesis was not confirmed by them. Additionally, they assumed a positive result of non-renewable energy and a negative result of renewable energy in EFP. Pata and Aydin (2020), studying the six largest hydropower-consuming countries, concluded that the EKC hypothesis is not confirmed in Brazil, China, Canada, Norway and the USA. Another study by Pata et al. (2021), where they used the Human Development Index instead of GDP to test the EKC hypothesis for the 10 countries with the highest EFP, also found negative results. Similar results were obtained by Mert and Bölük (2016), Begum et al. (2015), Ozturk and Al-Mulali (2015), Saboori et al. (2012).

In some studies, the environmental Kuznets curve takes the form of the letter N. For example, Alvarez-Herranz and Balsalobre-Lorente (2015) conducted studies on the relationship between economic growth, measured by GDP per capita, and greenhouse gas emissions per capita for 28 countries OECD. The results of the research allowed them to propose the thesis that the improvement of the environment, appearing after crossing the turning point, lasts only up to a certain level of economic development, followed by a renewed increase in degradation the environment. There may be several reasons for this phenomenon. One of them is the dominant role of the economies of scale related to the rapid increase in economic activity resulting in the use of a large amount of raw materials and an increase in the emission of pollutants and the amount of waste against the background of the technological and composition effect, i.e., changes in the economic structure of the country.

Most of the literature focusing on the EKC hypothesis uses the emission levels of CO_2 or similar greenhouse gases as a measure of environmental pollution. However, using CO_2 emissions as an indicator of the degree of pollution or environmental degradation means that only one of several dimensions of environmental pollution is considered (Ozcan et al., 2018). For this reason, in order to be able to assess the role that economic growth and energy consumption play in several dimensions of environmental degradation, a more comprehensive measure (Ozcan et al., 2019) is the Ecological Footprint. Human welfare largely depends on how we can obtain the necessary resources. As our planet has limited resources, we need to consider them and move to a sustainable development situation (Borucke et al., 2013). Hence, a derivative research direction in relation to the analysis of the relationship between GDP and the ecological footprint is the correlation of the ecological footprint with the sustainable development of the economy (Dembińska et al., 2018; Szopik-Depczyńska et al., 2018; Arbolino et al., 2018), sometimes in connection with security environmental (Li et al., 2019) or environmental quality assessment (Baz et al., 2020).

As an indicator of environmental degradation, the ecological footprint has recently received a lot of attention in the literature. However, considering the complexity of the relationship with economic development, it still remains poorly understood and largely neglected in making political decisions. This is especially true of holistic approaches, capturing groups of countries or continents, giving the possibility of comparative analyzes. This was the basis for undertaking the research presented in this article. The main research gap concerns the provision of information on changes in the management structure in the context of an increase/decrease in the ecological footprint. Research using shift share analysis fills this gap.

3. Methodology

3.1. The aim and hypothesis of the research

The aim of the research is to assess the changes that have occurred in the size of the ecological footprint and in its structure. The research was based on the following hypothesis: the size of the ecological footprint is positively correlated with the level of GDP. Additionally, an auxiliary hypothesis was adopted that the industrialization level of a given country increases with the increase in GDP, which determines the increase in the ecological footprint.

3.2. The shift-share analysis method

The shift-share method was applied as it allows for the decomposition of changes in total shift (TS) relative to another reference area for a specific variable into three additive components: national participation, sector structure, and region participation.

The assumptions of the analysis shift-share were first developed and described by Creamer in 1943. Then, in 1960 Dunn popularized this method in his work *"A statistical and analytical technique for regional analysis"* (Dunn, 1960). In its assumption, this method is used to describe regional and structural changes of the studied phenomenon, which allows the detection of changes in the competitive position of the studied region against the background of the reference unit. In the early 1980s, this method was often used by many economists in the sphere of marketing as well as in urban research. In 1980 Stevens and Moore emphasizing the simplicity of the method, stated that the SSA method is a useful tool in identifying changes in the studied phenomenon (Stevens and Moore, 1980).

The purpose of the shift share analysis (SSA) is to compare the sectoral growth distributions of the economic phenomenon under study between two geographical areas (usually a region relative to the area of the country or other reference area as a whole) in order to answer three questions: Does the regional economic structure bring more growth than the domestic one? Is the regional growth of the sector higher on average than the domestic one? Which of the sectoral structures or effectiveness contribute more to the observed diversification of the combined growth of economic phenomena between the region and the country? (Artige and van Neuss, 2014).

The use of shift share analysis allows for the parameterization of economic changes in three dimensions. The first is to calculate the potential of individual countries against the background of the entire European Union. The second is to study the structure of the ecological footprint in individual countries, the third and last dimension is the parameterization of the competitiveness of countries due to the ecological footprint.

Shift share analysis has generally been used for describing regional and industrial economic growth and examining the structural effect and regional or industrial competitiveness underlining the changes over time (Stevens and Moore, 1980). It has been popular in the fields of regional economic, political economy, marketing, geography, and urban studies for about four decades (Tłuczak, 2015; Trzpiot, 2013; Szewczyk and Zygmunt, 2011; Suchecki, 2010; Toh et al., 2004; Toh et al., 2003; Stevens and Moore, 1980).

In the classic analysis of share shifts, the formation of the quantized TX variable is examined in the form of a complex absolute increase or the rate of change (Tłuczak, 2015; Trzpiot, 2013; Suchecki, 2010). The use of SSA analysis in the development of a given socio-economic phenomenon involves decomposing the total change of a localized variable into three components (Tłuczak, 2015):

$$tx_{ri} = tx_{..} + \sum_i w_{r.(i)}(tx_{.i} - tx_{..}) + \sum_i w_{r.(i)}(tx_{ri} - tx_{.i}) \quad (1)$$

where:

$m = tx_{..} = \frac{\sum_{r=i}^{R}\sum_{i=1}^{S}(x^*_{ri} - x_{ri})}{\sum_{r=i}^{R}\sum_{i=1}^{S}x_{ri}}$ - the national (global) regional growth factor;

$e_i = tx_{.i} - tx_{..} = \frac{\sum_{r=1}^{R}(x^*_{ri} - x_{ri})}{\sum_{r=i}^{R}x_{ri}} - \frac{\sum_{r=i}^{R}\sum_{i=1}^{S}(x^*_{ri} - x_{ri})}{\sum_{r=i}^{R}\sum_{i=1}^{S}x_{ri}}$ - the sectoral (structural) factor of regional growth;

$u_{ri} = tx_{ri} - tx_{.i} = \frac{x^*_{ri} - x_{ri}}{x_{ri}} - \frac{\sum_{r=i}^{R}(x^*_{ri} - x_{ri})}{\sum_{r=i}^{R}x_{ri}}$ - the local (geographical, competitive, differentiating) growth factor in the i-th sector of the r-th region;

$w_{r.(i)} = \frac{x_{ri}}{x_{r.}}$ - regional weights;

x_{ri}- the value of the analyzed variable in the r-th region in the i-th cross-sectional group in the initial period;

x^*_{ri}- the value of the analyzed variable in the r-th region in the i-th cross-sectional group in the final period.

By transforming Eq. (1) into the form (Szewczyk and Zygmunt, 2011):

$$tx_{ri} - tx_{..} = \sum_i w_{r.(i)}(tx_{.i} - tx_{..}) + \sum_i w_{r.(i)}(tx_{ri} - tx_{.i}) \quad (2)$$

pure regional growth was obtained (tx_{ri} and $- t_{..}$) defined as the difference between regional and national growth rates.

The relation described by Eq. (2) is called structural-geographical equality, in which the geographical differentiation of the surplus of the average regional growth rate over national growth is decomposed into two effects:

- a structural one: $s_r = \sum_i w_{r.(i)}(tx_{.i} - tx_{..})$ - which is equal to the weighted average deviation by average growth rates in sectors and the national growth rate and indicates that variations in distribution differentiate regions. The structural effect informs that the average rate of regional growth of the studied phenomenon in the indicated areas may vary inter-regionally due to differences in the structure of the analyzed phenomenon.

– a geographical one: $g_r = \sum_i w_{r.(i)}(tx_{ri} - tx_{.i})$ - defined as the weighted average of regional deviations attributing categories of the cross-sectional qualitative criterion to the respective regions. The geographical effect also called the regional competitiveness effect, is the most important of the effects because it explains how much of the change in a given area is due to the region's unique competitive advantage because growth cannot be explained by national trends in this area as a whole. This effect is calculated by taking the total regional growth and subtracting the effects of national growth and structural effects. It should be noted that this effect may be higher than the actual increase in the given area, even if the mixed effects at the national and/or structural level are negative.

4. Results and discussion

4.1. Analysis of the ecological footprint and intensity indicator values

From the ecological footprint analysis point of view, the key factor seems to be the spatial development structure that reflects the reproductive potential of natural resources. It should be assumed that the more built-up areas that are the result of human activity and human intervention in the natural environment, the greater the ecological footprint. Thus, in order to verify such a hypothesis, one should seek an answer to the question to what extent the spatial development structure affects the amount of the ecological footprint. For this purpose, the intensity index was calculated, which is the ratio of the area of green areas to the area of built-up areas. Data was downloaded from the Global Footprint Network. In the years 2009, 2014, 2019 the advantageous relation of both plots persists, allowing for the conclusion that in the studied countries the area of green areas exceeds the area of built-up areas. The average value of the index remains at a similar level in the analyzed period, and there were no significant changes in terms of variation coefficient (Table 1).

While analyzing the distribution of ecological footprint and intensity indicator values for individual countries, one can observe countries that significantly stand out from the rest. On the one hand, Spain, Portugal and Slovenia stand out due to the intensity indicator. These are the countries where the ratio of green areas to built-up areas is the most favorable. On the other hand, countries such as Germany, France and the United Kingdom are countries with a high degree of urbanization and high ecological footprint values at the same time. Our research results are therefore consistent with those presented in the literature (Balsalobre-Lorente et al., 2022; Ioppolo et al., 2014) (Fig. 1).

As a result of the use of hierarchical methods, a dendrogram was obtained that illustrates the hierarchical structure of a set of objects due to the decreasing similarity between them. First, the Ward method of grouping the characteristics directly influencing the phenomena related to the ecological footprint in the European Union countries is presented. The dendrogram in 2019 shows three groups of objects (Fig. 2), they are respectively:

Group 1: Austria, Sweden, Denmark, Bulgaria, Ireland, Hungary, Czech Republic, Portugal, Romania;

Table 1
Basic descriptive statistics of the intensity indicator in 2009 and 2014 and 2019.

Variable	Mean	Min	Max	Standard deviation	Variation coefficient
intensity indicator_2009	21,10	7,81	52,00	13,17	62,42
intensity indicator _2014	20,33	7,14	50,00	11,91	58,60
intensity indicator _2019	1,28	178,89	35,44	0,20	1,28

Source: own elaboration.

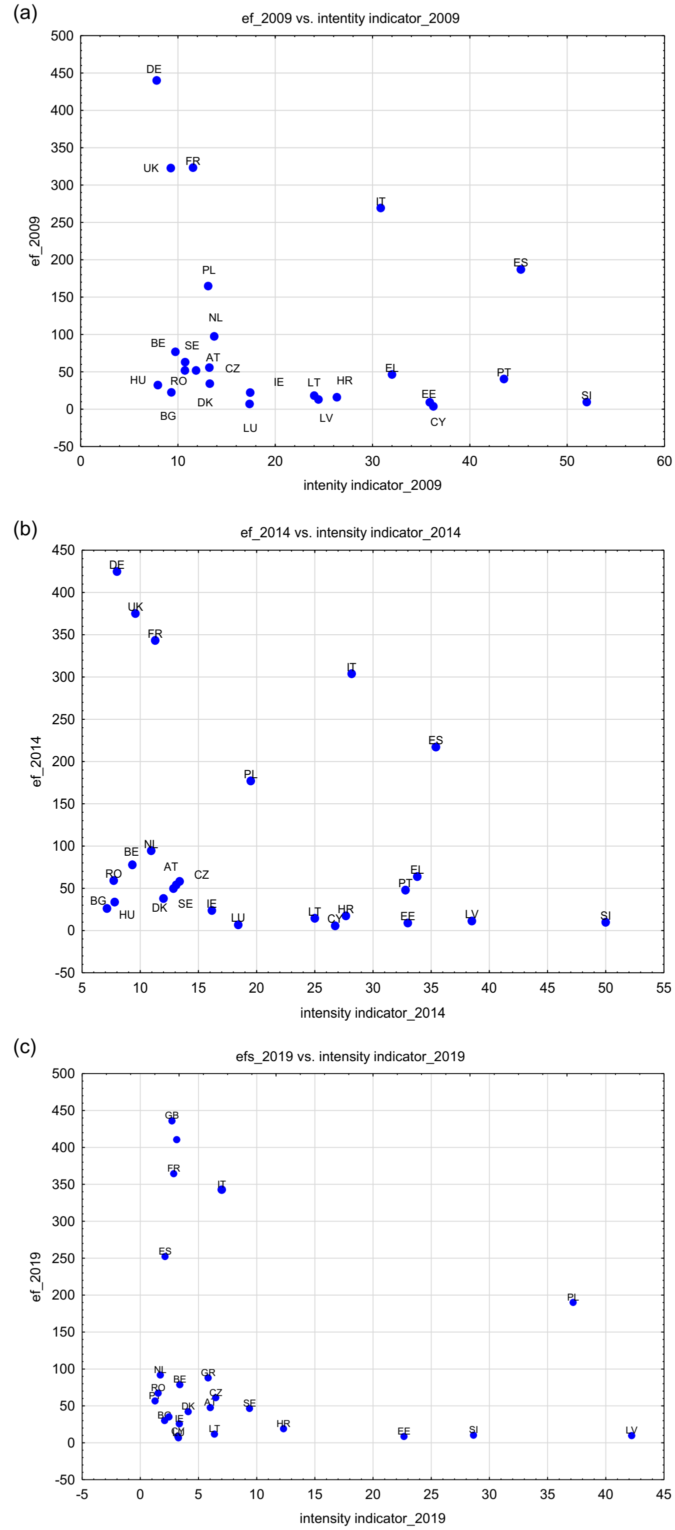
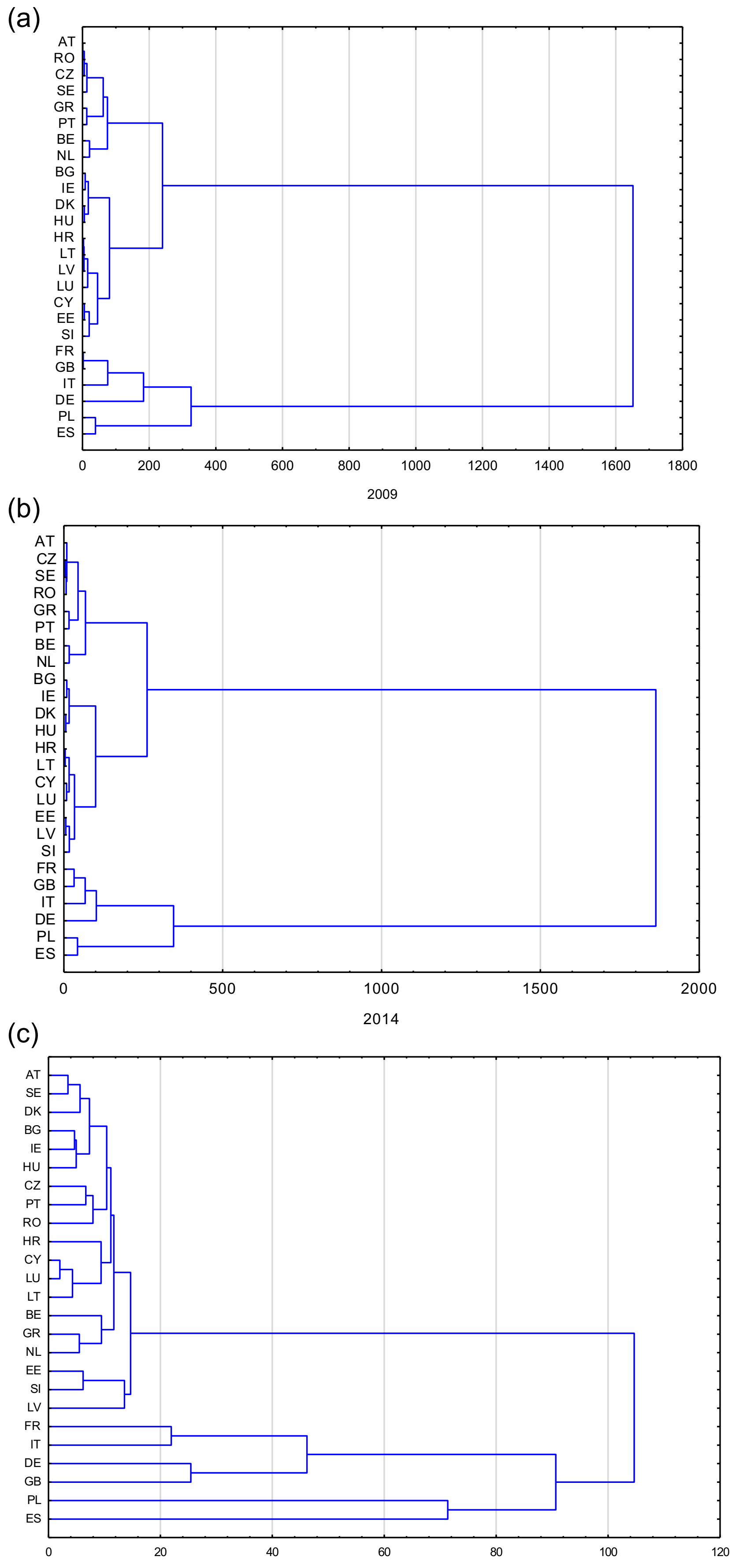


Fig. 1. a. Ecological footprint and intensity indicator in 2009.
1b. Ecological footprint and intensity indicator in 2014.
1c. Ecological footprint and intensity indicator in 2019.
Where the country codes used by Eurostat and national statistical institutes have been used: AT-Austria, BE – Belgium, BG – Bulgaria, HR – Croatia, CY – Cyprus, CZ – Czech Republic, DK – Denmark, EE – Estonia, FR – France, GR – Greece, ES – Spain, IE – Ireland, LT – Lithuania, LU – Luxemburg, LV – Latvia, MT – Malta, NL – Netherlands, DE – Germany, PL – Poland, PT – Portugal, RO – Romania, SK – Slovakia, SI – Slovenia, SE – Sweden, HU – Hungary, GB – United Kingdom, IT – Italy.
Source: own elaboration.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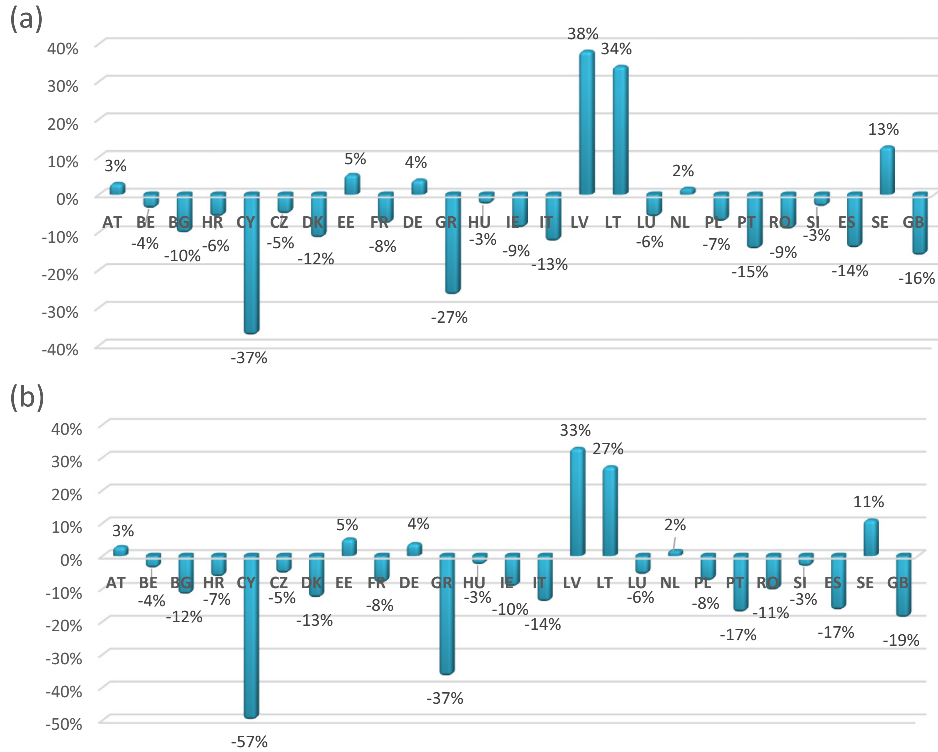


Fig. 3. a. Changes in the size of the ecological footprint in 2009–2014.
3b. Changes in the size of the ecological footprint in 2014–2019.
Source: own study based on Global Footprint Network data.

Group 2: Croatia, Cyprus, Luxembourg, Lithuania, Belgium, Greece, Netherland, Slovenia, Latvia;
Group 3: France, Italy, Denmark, United Kingdom, Poland, Spain.

The created hierarchical structure indicates the greatest distance between the countries from group 1 and countries from group 3, the countries within the groups are similar to each other. The search for similarities between countries in the area of ecological footprint research using the Ward's method showed that the formed clusters largely depend on the values of the components of the variables included in the analysis. Ward's method seems to be an advantageous method in obtaining relationships between countries regarding the variables described above. The results of the shift share analysis will be supplemented.

4.2. Analysis of the changes in the size of the ecological footprint in 2009–2014 and 2014–2019

The analysis of the structure of the ecological footprint components was performed for the EU member states in relation to the level of phenomenon development in the European Union. Test data was downloaded from the Global Footprint Network. They describe the size of the ecological footprint in individual countries ($r = 1, \ldots, 25$) and its structural division ($I = 1, \ldots, 6$; cropland, grazing land, fishing grounds, built-up land, forest area, and carbon demand on land). The time scope of the study covered the years 2009 and 2014. Despite the fact that the variables are correlated with each other, an analysis of structural changes was undertaken in order to identify changes in the footprint level due to the structure of the analyzed variables.

Comparing the rate of increase/decrease in the size of the ecological footprint in individual countries in 2009–2014 with the average decrease ecological footprint of 3.8 %, it is possible to distinguish regions with a higher level of changes in the phenomenon than the EU rate: Bulgaria, Cyprus, Denmark, France, Greece, Italy, Luxembourg, Poland, Portugal, Spain, Romania, Great Britain. A slower pace of change than the EU pace (the ecological footprint is lower than in the EU), were recorded in other countries (Fig. 3). The largest changes in the demand for natural resources of the biosphere in hectares of land and sea were recorded in Latvia and Lithuania - these were, unfortunately, negative changes, a tenfold increase in the value of the ecological footprint. However, in Cyprus, the largest decrease in the size of the ecological footprint (-36.7 %) among all countries can be observed. This is obviously a positive effect on the environment in this country and results from changes in the ecological footprint structure at the level of -1.6 % and those resulting from changes in the competitive effect which measures the impact of the difference between the growth rate of the ecological footprint of the studied country and the growth rate in the European Union.

4.3. Analysis of the structural and regional effect in ecological footprint for selected countries UE

Within the individual components making up the ecological footprint, the differences in changes that occurred in 2009–2014 and 2014–2019 were visible (Fig. 4a and b).

Fig. 2. a. Ecological footprint and intensity indicator in 2009.
2b. Ecological footprint and intensity indicator in 2014.
2c. Ecological footprint and intensity indicator in 2019.
Where the country codes used by Eurostat and national statistical institutes have been used: AT-Austria, BE – Belgium, BG – Bulgaria, HR – Croatia, CY – Cyprus, CZ – Czech Republic, DK – Denmark, EE – Estonia, FR – France, GR – Greece, ES – Spain, IE – Ireland, LT – Lithuania, LU – Luxemburg, LV – Latvia, MT – Malta, NL – Netherlands, DE – Germany, PL – Poland, PT – Portugal, RO – Romania, SK – Slovakia, SI – Slovenia, SE – Sweden, HU – Hungary, GB – United Kingdom, IT – Italy.
Source: own elaboration.

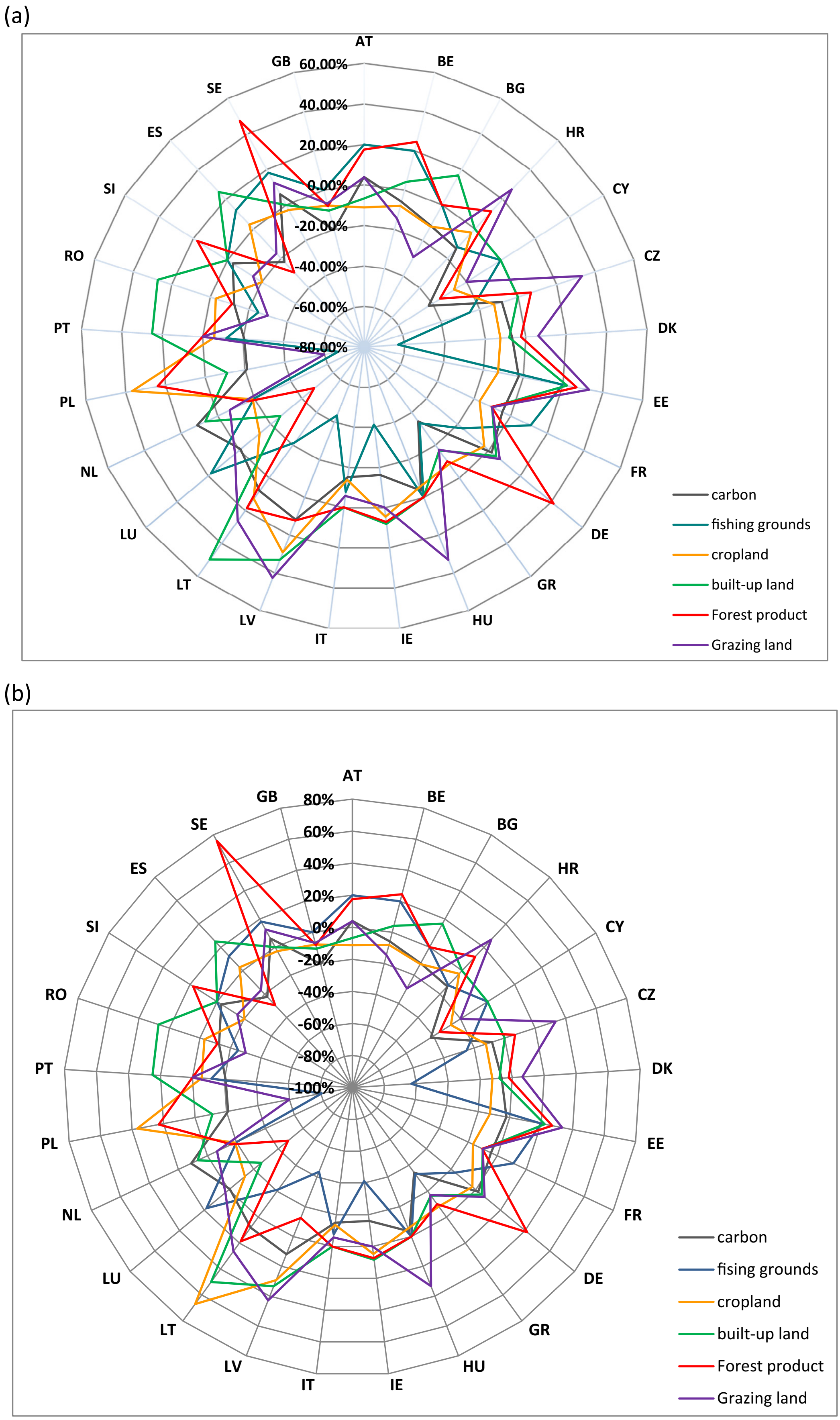
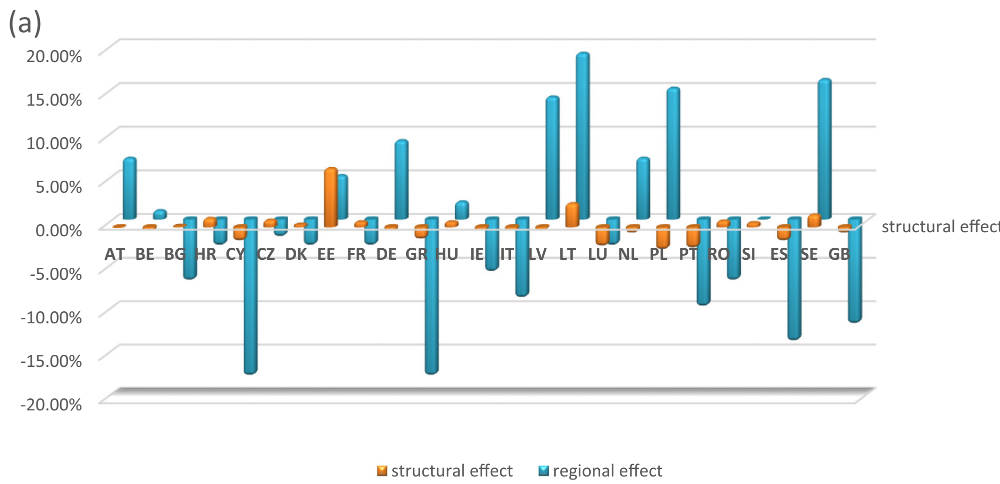


Fig. 4. a. Structure of changes in ecological footprint in 2009–2014.
4b. Structure of changes in ecological footprint in 2004–2019.
Source: own study based on Global Footprint Network data.



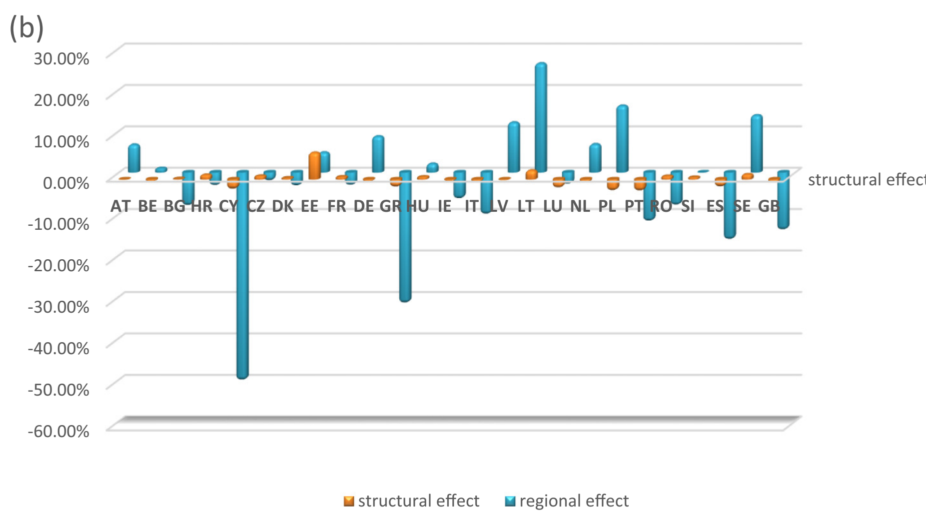


Fig. 5. a. Structural and regional effect for selected countries UE in 2009–2014.
Source: own elaboration.
5b. Structural and regional effect for selected countries UE in 2014–2019.
Source: own elaboration.

The biggest changes took place within the fishing grounds. In the years 2009–2014 and 2014–2019 there was a decrease by 24.5 % and 23.46 %. This was on average 19.8 % more than the overall decline in EF for all EU countries. Similar research results, but for 11 provinces in China shows Kong et al. (2021). This allows us to say that the ecological security of global marine fishery is facing severe threat because overfishing contributes to drastic declines in sustainable fishing yields and generally curtails the ecological resilience of marine systems. On the other hand, marine fishery ecological system provides an essential source of economic livelihood for populations throughout the world. Thus, sustaining marine fishery ecological security is essential for the future of economic and food security. Therefore, there is a strong need for joint management of fish stocks in order to reverse future patterns of the fishing footprint. Common benchmarks should be set within EU policy. EU countries should strive to tighten the rules on penetration of fisheries. This runs counter to economic goals as fish and other marine resources are the basic economic resources.

The smallest changes, even insignificant, were recorded for cropland, here there was a decrease of only 0.60 %. But it should be noted that croplands are heterogeneous in productivity. When analyzing individual values of changes within individual EF categories, only positive or only negative values were found in none of them. This may mean that individual countries pursue different policies in the field of environmental protection. Land use optimization is an integral part of the land use conflict resolution process (Dembińska, 2010). Particular attention should be paid to optimizing the spatial distribution of urban land and arable land in order to balance the arable land resources and their negative impact on ecological land in line with the spatial heterogeneity of agricultural production on the land. Because, as Tang et al. (2021) notice, when cropland expansion encroaches on ecological land, e.g., forest, grassland, wetland, it seriously affects carbon storage which plays an important role in global climate change (Fig. 5).

Changes that have taken place in the demand for natural resources of the biosphere in hectares of land and sea surface result from changes in the structure of this demand, as well as were caused by internal changes in individual countries related to competitiveness with other countries. As the analysis showed, the level of demand for natural resources in the biosphere in hectares of land and sea generates changes in EF values. It should be noted, however, that the most significant decreases in the value of the EF indicator need not be directly related to revolutionary changes within the framework of sustainable development policy or straightforward environmental protection. The level of industrialization of selected countries and their import demand is essential. The above changes may result from lower demand supplemented or balanced by imports of goods from other countries, which in turn means an increase in the EF index in exporting countries.

These changes have certainly contributed to improving the quality of the environment. The reduction in EF could be *in plus* or *in minus*. Each time these changes should be considered in relation to the structural and geographical effect. The geographical effect proving the improvement or the deterioration of a country's competitive position concerning neighboring countries has the highest values for Austria, Cyprus, Denmark, Greece, Lithuania, Latvia, Poland, Portugal, Spain, Sweden, and Great Britain. For eight of the countries listed, there is a noticeable improvement in competitive position (positive geographical effect); for the remaining countries, there is a deterioration.

5. Conclusions

Ecological footprint is an important indicator that shows how human activities reduce environmental quality among a specific region or country. In our research we indicate that the spatial development structure affects the level of the ecological footprint. On the other hand, the way of spatial development is a problem of using natural resources. Rational shaping of the structure of the use of natural resources in the process of spatial development is the basic goal of sustainable development.

We have demonstrated that, from an ecological footprint analysis perspective, the key factor is the land use structure, which reflects the reproductive potential of natural resources. The hypothesis is true that the more built-up areas resulting from human activity and human interference with the natural environment, the greater the ecological footprint. Countries and time-period were selected on data availability. This study contributed to the related literature by examining the validity of the EKC hypothesis with consideration of the EFP as a multiaspect indicator of environmental quality.

Europe's environmental deficit is large. The overall use of ecological resources and waste emissions far exceed Europe's biological capacity. This means that our continent is unable to sustainably meet consumer needs within its own borders. One way to alleviate this problem is to develop a circular economy. The transition to a circular economy is a visible EU priority. The European Green Deal sets out an ambitious agenda to transform the EU into a fair and prosperous society, a resource-efficient, low- and zero-carbon, and competitive economy. A circular economy requires minimizing resource consumption by using as few resources as possible, keeping materials and products in the economy for as long as possible, and using the waste generated to reintroduce waste materials into the economy. These resource savings are intended to imply climate change mitigation. Therefore, it is necessary to postulate that the transformation of the current model of the EU economy into a circular economy model should be accelerated. The attitudes of individual member states play a key role here. Environmental awareness, manifested in specific actions, is, however, characterized by a non-uniform level across all EU countries. Therefore, action should be taken at the EU level to solve this problem. Apart from educational activities, it is possible to extend the legal regulations concerning entrepreneurs, especially those sectors of the economy which have the greatest negative impact on the environment. Additional taxes are an effective tool - in this case, they may refer to the failure to apply the circular economy guidelines not only to the main processes or services, but also to auxiliary or administrative activities. The order element can act as a stimulant.

Reservations can be made against the spatial development policy. The intensification of land use for economic purposes is mainly related to population growth, the processes of urbanization and industrialization, the development of transport infrastructure and the development of tourism. Europe cannot pursue its recent land take trends as the continued loss of ecosystem services as a result of landscape defragmentation is exacerbating natural disasters and impoverishing biodiversity. Hence, it is necessary to restore wetlands, peat bogs, coastal ecosystems, forests and meadows. It is essential that the EU sets short and long-term goals for land-use policy. An important element of this policy should be soil productivity management. Highly productive land with high biodiversity should be protected, and if it were to be used, then a restriction or compensation mechanism could be introduced. Land use efficiency can also be increased by promoting land recycling or introducing various financial instruments, e.g., subsidies, tax cuts, co-financing of investments. Recycling land is part of the circular economy model. Actions should be carried out in three directions: reconstruction of land previously developed for economic purposes - gray recycling, ecological modernization of land for soft use (e.g., green areas in city centers) and land renaturation (restoring it to nature) by removing existing structures and/or surface sealing - green recycling. It is important that the areas once "taken" from the natural environment and transformed (eg for the construction of a motorway) are used by humans to the maximum (effectively). The challenge is to stop the "looting" of new land and to prevent the so-called "spilling" of cities.

Another problem is the ineffectiveness of the EU's fisheries policy, and more precisely the ineffectiveness in respecting the level of "maximum sustainable yield". The fisheries reporting and control system needs to be strengthened. In the field of sustainable maritime affairs, funding should be expanded to clean the seas and oceans of waste.

Continuation of research is justified. Our methodology can be extended by introducing into the analysis various factors in the character of stimulants and destimulants. Interesting research on the ecological footprint will also be made using the perspective of the COVID-19 pandemic or the war in Ukraine. Moreover, we believe that extending the time perspective to earlier years or applying a comparative approach taking into account other continents may also bring interesting results. However, conducting research on this topic has some limitations - they are determined by the availability and timeliness of data.

CRediT authorship contribution statement

Izabela Dembińska: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Visualization, Supervision, Funding acquisition, Project administration, Writing - original draft, Writing - review & editing. **Sabina Kauf:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Funding acquisition. **Agnieszka Tłuczak:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Funding acquisition. **Katarzyna Szopik-Depczyńska:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Funding acquisition. **Łukasz Marzantowicz:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Funding acquisition. **Giuseppe Ioppolo:** Conceptualization, Formal analysis, Investigation, Supervision.

Data availability

Data was downloaded from the Global Footprint Network

Declaration of competing interest

Izabela Dembińska, Sabina Kauf, Agnieszka Tłuczak, Katarzyna Szopik-Depczyńska, Łukasz Marzantowicz and Giuseppe Ioppolo - all the authors of the manuscript titled " THE IMPACT OF SPACE DEVELOPMENT STRUCTURE ON THE LEVEL OF ECOLOGICAL FOOTPRINT IN SELECTED EUROPEAN COUNTRIES" declare no conflict of interest.

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