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# GREEN ECONOMY INDICATOR AND THE LEVEL OF SOCIO-ECONOMIC DEVELOPMENT – MEASUREMENT AND IMPLICATIONS AT PROVINCIAL LEVEL

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ABSTRACT: The subject of the article was issues related to the green economy and the Human Development Index (HDI). Its aim was to check whether there is any differentiation in the level of the green economy in the surveyed provinces (voivodeships) and to identify the links between the level of the green economy and the HDI index. The main research problem formulated in the form of a research question was: Is the level of the green economy linked to the Human Development Index? In the first step of the research process, the level of the green economy was determined in regional terms. It was based on the most up-to-date data available. They concerned the year 2022 and were taken from the Central Statistical Office database. Out of the 69 measures included in the database, 16 measures have been selected. In the next step, the results obtained during grouping were compared with the Human Development Index. The study used correlation analysis, a taxonomic method of grouping objects – the Ward method and the non-parametric Kruskal-Wallis H test. Grouping made it possible to diagnose the degree of differentiation of the green economy in the voivodeships and create clusters of similar voivodeships in terms of the level of the green economy. The Kruskal-Wallis H test made it possible to check whether the level of the green economy is linked to the HDI. As a result of these activities, the resulting clusters were compared, and conclusions were formulated. Analyses showed that the level of the green economy varies significantly between voivodeships. However, no statistically significant correlation was found between the level of green economy and the HDI index.

KEYWORDS: green economy, Human Development Index, cluster analysis, Poland, provinces (voivodeships)

## Introduction

The green economy is a sustainable way of doing business. It respects natural resources and seeks to ensure sustainable social and economic well-being. The green economy is a non-directly measurable phenomenon that can be studied using a number of appropriately selected indicators (Juszczak & Rabiega, 2021), grouped according to different criteria. In order to learn about the differentiation of the state of the green economy in individual Polish provinces, the study conducted a cluster analysis, which made it possible to isolate provinces that are similar in terms of the characteristics of the green economy. The main aim of the study was to compare green economy indicators with a measure of human development and to see if there was a statistically significant relationship between the resulting regional clusters and the level of HDI. There are no studies in the literature that examine the relationship between the state of the green economy, as measured by such a large number of indicators, and the level of the HDI. Therefore, the research concept responds to the identified research gap. The main research question was: is the level of the green economy related to the Human Development Index? The specific questions were formulated as follows:

- *Q1: Does the state of the green economy differ between provinces?*
- *Q2: Are there provinces with similar characteristics that describe the green economy?*

The analyses and conclusions contained in the study may prove useful to entrepreneurs, representatives of local authorities, decision-makers interested in the level of development of the green economy and its impact on the life of local communities.

The article contains: (1) a literature review covering the characteristics of the green economy with particular emphasis on its economic dimension, as well as the relationship between the green economy and the indicators of social development (in this part, bibliometric analysis was used); (2) a description of the research methods used; (3) a description of the research carried out; (4) a discussion; (5) the most important research conclusions and recommendations.

## Green Economy

"The green economy" is a concept for a new approach to shaping industrial production structures, it is a practical way of implementing the principles of sustainable development and the fight against poverty. These issues are related to a low-carbon economy, which highlights the need to reduce greenhouse gas emissions, which are dominated by carbon dioxide (Górka & Luszczyk, 2014). The concept can be considered from three perspectives: (1) conceptual-theoretical (it is relevant for strategy formulation, policy making and development programme design), (2) application-implementation (it then includes elements such as green products and services, green investments, green economic sectors, green procurement, green taxes and other governance instruments, green jobs and green economy friendly consumption) and (3) measuring the results of its implementation (Adamowicz, 2022; Lin & Zhu, 2019).

The term "green economy" has gained prominence as a result of the real economic crisis that began in 2008. Its origins can be traced back to 1989, when it was first used in the *Blueprint for a Green Economy* report prepared for the UK government (Szyja, 2014). The aim of the report was to assist the UK government in implementing the concept of sustainable development (GUS, 2023). The term "green economy" has been introduced by economists and politicians to describe ways of doing business that maximise the use of biological processes to produce goods and services that serve people in production processes and meet consumption needs (Adamowicz, 2021). This concept focuses on the relationship and interdependence between the economy and the ecosystem and provides a basis for operationalising the concept of sustainability (Adamowicz, 2022; Sanchez-Loor & Chang, 2013). The use of the adjective "green" in relation to economic phenomena is a symbolic way of drawing attention to the importance and need to protect the natural factor in the economy (Adamowicz, 2022). The green economy refers to natural biological processes and the primary production of plants. It involves reducing energy consumption based on traditional raw materials, increasing energy and raw material efficiency and increasing the share of energy from renewable sources (Ochab et al., 2017). It should lead to improvements in human well-being and social equity, while contributing to the reduction of environmental risks and ecological scarcity (Szyja, 2014; Kowalska et al.,

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2022). In the European Union, the green transition is considered a key factor for future economic growth (Juszczak & Rabiega, 2021). The creation of a green economy aims, among other things, to achieve the following objectives (Szyja, 2014; Adamowicz, 2022):

- Increase energy and resource efficiency and energy security,
- Reduce greenhouse gas emissions (particularly carbon dioxide),
- Reduce pollution from production processes,
- Eliminating environmental risks and preserving their value,
- Social inclusion and economic efficiency,
- Mobilising the use of innovation potential,
- Achieving new competitive advantages.

In a green economy, income and employment growth should be driven by public and private investments that reduce carbon emissions and pollution, increase energy efficiency and prevent the loss of biodiversity and ecosystem services. These investments need to be catalysed and supported by targeted public spending, policy reforms and regulatory changes (Barbier, 2016).

The green economy should also be socially inclusive (Loiseau et al., 2016), that is, it should emphasise "harmonious and balanced relationship among economic, social, and ecological systems" (Fan et al., 2023). It also means "pursuit of economic growth while paying attention to social well-being" (Fan et al., 2023). It is therefore essential for the proper and sustainable development of economies to take into account of both economic development, with its social elements, and respect for the environment.

Closely related to the term green economy is "green growth". Together, they are identified as key elements of sustainable development (Mentes, 2023). However, they are not identical concepts. The green economy is concerned with the state and structure of the economy, its specificities and how it functions, while green growth is dynamic and refers to the use of green factors to increase economic outcomes (productive resources, production, consumption, income) that can lead to development. Green growth is quantitative (Adamowicz, 2022), it is a tool for achieving the green economy, and the green economy is one of the instruments of sustainable development (GUS, 2023). Both concepts aim to promote a shift towards more sustainable production and consumption patterns, taking into account social equity and environmental sustainability. The implementation of green economy and green growth policies can contribute to the achievement of the Sustainable Development Goals, as well as create new employment opportunities and improve the well-being of society (Mentes, 2023). The World Bank emphasises that green growth is also qualitative growth that is efficient in its use of natural resources, clean because it minimises pollution and environmental damage, and resilient because it clarifies natural hazards (Loiseau et al., 2016; Mealy & Teytelboym, 2022). A prerequisite for green growth is the development and diffusion of innovative technologies and products that benefit the environment (Mealy & Teytelboym, 2022).

## The economic dimension of the green economy

The green economy is linked to the concept of sustainable socio-economic development. It is therefore closely linked to economic policy, particularly in the areas of energy and industry, and to some extent is implemented at the company level. The principles of sustainable development are being implemented as part of the social and economic development agenda at the level of governments and international organisations. Linking business and the green economy is about integrating economic and environmental objectives to create sustainable business models that not only generate profits but also have a positive impact on the environment and local communities (Jezierska-Thöle et al., 2022). The green economy emphasises sustainability, environmental protection and the use of renewable resources – it therefore has specific economic dimensions that relate to both the costs and benefits associated with the green transition (Table 1).

Table 1. Costs and benefits of the green economy

| Costs | Benefits |
|---|---|
| • Investment<br>• Operational<br>• Social<br>• Educational and training | • Increased energy efficiency<br>• New jobs<br>• Climate Change<br>• Development of innovation<br>• Local economic and community development<br>• Benefits from exports and know-how |

The transition to a green economy requires significant investment in infrastructure (renewable energy sources, advanced technologies, transmission networks, etc.). Any change in this area requires investment. Their costs are mainly related to research, but also to the development of new technologies, such as photovoltaic panels, wind farms and energy storage systems (Ochab et al., 2017). It is also essential to convert fossil fuel-based sectors (coal, oil) to greener ones, which may prove more costly, involving the modernisation of factories, transport and energy systems. According to the Report of the Polish Electricity Committee from 2022 (Polski Komitet Energii Elektrycznej – PKEE, 2022), investments in the transformation of the energy market in Poland will amount to up to EUR 135 billion (PLN 600 billion) by 2030 (Polski Komitet Energii Elektrycznej – PKEE, 2022). Operating costs associated with the green economy include legal and environmental compliance costs. Initially, green technologies such as photovoltaics and wind power may have higher operating costs than traditional forms of energy, but these will steadily decrease. The costs of adapting to environmental regulations and meeting new standards, e.g. for $CO_2$ emissions, water consumption or waste management, are also significant. Environmental transformation has social costs that are often difficult to put a price on (Görg et al., 2017). The economic transition to a green economy may also lead to a short-term decline in employment in carbon-intensive sectors (mining, petrochemicals). Retraining workers, particularly in regions dependent on traditional energy sources, can be lengthy and costly. The green economy is about public awareness. Ongoing education and training is both time-consuming and costly. Therefore, many local and community-based initiatives have been developed to raise public awareness of the transition (Kosheleva, 2024). While there are costs associated with the green economy, it should also be emphasised that there are a number of benefits associated with the green transition. Green technologies, such as renewable energy, bring long-term savings. After the initial investment, the cost of producing energy from photovoltaic panels or wind farms is lower than from fossil fuels because they do not require the purchase of raw materials (Ochab et al., 2017). It is worth mentioning the savings from energy efficiency (e.g. better insulation of buildings, energy-efficient technologies in industry), which lead to lower energy bills. To this end, the European Union's energy policy is changing. The European Council has introduced several directives aimed at improving the energy efficiency of buildings, which will undoubtedly result in savings for residents and users (Directive, 2010; Directive, 2018). The green economy is creating new jobs in sectors such as renewable energy, recycling, waste management, green buildings and low-carbon transport. In 2018, the European Commission highlighted that there are 4 million green jobs in the EU and that action to meet energy targets by 2020 will lead to an increase in employment of 1-1.5%. Moreover, the progressive green transformation should create more and more "new and attractive" jobs (Komisja Europejska, Dyrekcja Generalna ds. Działań w dziedzinie Klimatu, 2019). In Poland, it is estimated that the energy transition will lead to the creation of around 300,000 new jobs in industries with a high greening potential – mainly renewable energy sources, nuclear power, electromobility, grid infrastructure, digitalisation and thermo-modernisation of buildings (Ministerstwo Klimatu i Środowiska, 2021). Improved public health associated with lower emissions (cleaner air and water) is also an important consideration. Such measures reduce healthcare costs and increase employee productivity. The European Union aims to improve air quality every year. The green economy also promotes technological innovation that can benefit other sectors of the economy (Aldieri & Vinci, 2018). Developments in renewable energy, energy storage, smart grids and energy efficiency are driving other sectors, including IT. Innovative agricultural solutions (e.g. regenerative agriculture, water-saving technologies) are also becoming profitable, leading to increased yields and reduced consumption of natural resources.

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Local communities also benefit from the transition to a green economy, which can support their economies, particularly through decentralised energy production. Investment in renewable energy can generate local income and employment. One of the biggest advantages of green energy is that it is decentralised, meaning it can be produced almost anywhere where the natural conditions are right. This has a positive impact on the region's industrial processes. This is particularly important for small and medium-sized enterprises and for the economy in underdeveloped areas, especially rural areas. Businesses in these areas may not have access to extensive energy infrastructure, and the cost of bringing distribution networks to remote locations can affect the viability of projects (CEO, 2024). Profits can also be made from green projects, such as energy co-operatives, which encourage interaction between local communities and strengthen their energy self-sufficiency. Countries that develop advanced green economy technologies can become exporters to global markets. China and European countries export renewable energy technologies, including know-how, which brings them additional profits (Pawłowska-Kawa, 2024).

The transition to a green economy can bring a number of benefits. There are initial investment, operational and social costs, but the long-term benefits outweigh these costs. The green economy saves energy, creates new jobs, reduces health costs and reduces negative environmental impacts, which will be key to sustainable and balanced economic development in the future. Combining the economy with the green economy creates the opportunity to build a new kind of economy – one that is more sustainable, more equitable and more socially responsible. The green economy, which emphasises sustainability, environmental protection and the use of renewable resources, has specific economic dimensions. These relate to both the costs and benefits of the green transition.

## The green economy and HDI

The study sought to compare green economy indicators with the Human Development Index (HDI), one of the most widely used synthetic measures of socio-economic development. It reaches values from 0 to 1. It aims to capture the idea of social development by focusing on three dimensions: a long and healthy life, knowledge and a decent standard of living. Its undoubtedly innovative nature is due to the fact that it is a measure of human development, indicating both social and economic development at the same time (Migała-Warchoł, 2021). It was developed in 1990 by economists Mahbub ul Haq from Pakistan and Amartya Sen from India (awarded the Nobel Prize for Economics in 1998) (Dąbrowa, 2018). It was introduced by the United Nations in 1993 for international comparisons (Migała-Warchoł, 2017). It is calculated for all countries in the world and presented in the Human Development Reports (Laskowska & Dańska-Borsiak, 2018). The motivation for creating it was to find a measure that could focus directly on people's lives. This made it possible to formulate answers to the questions: *Who are the people? What do they do?* The HDI shows that human well-being is central to the development process and that people are an important economic resource (Pengo Bagolin & Comim, 2008). The indicator itself has been systematically revised. After the following changes in 2010, the HDI as a synthetic measure is based on the average of indicators relating to four themes (Tobiagi et al., 2023; Migała-Warchoł, 2021; Migała-Warchoł & Sobolewski, 2021):

1) life expectancy,
2) average years of education of residents aged 25 and over,
3) expected years of education of children entering the education process,
4) national income per capita in USD, calculated at purchasing power parity of the currency.

Due to the broad understanding of the relationship between socio-economic development and the green economy as well as the objectives of this article, it was decided to conduct a systematic literature review. In the first stage of the review, it was decided to select a bibliographic database that would allow a detailed analysis of scientific publications. The SCOPUS database was chosen for this purpose. In the second stage, the keywords considered and the conjunctions linking the phrases were developed. This resulted in combinations presented on the Figure 1.

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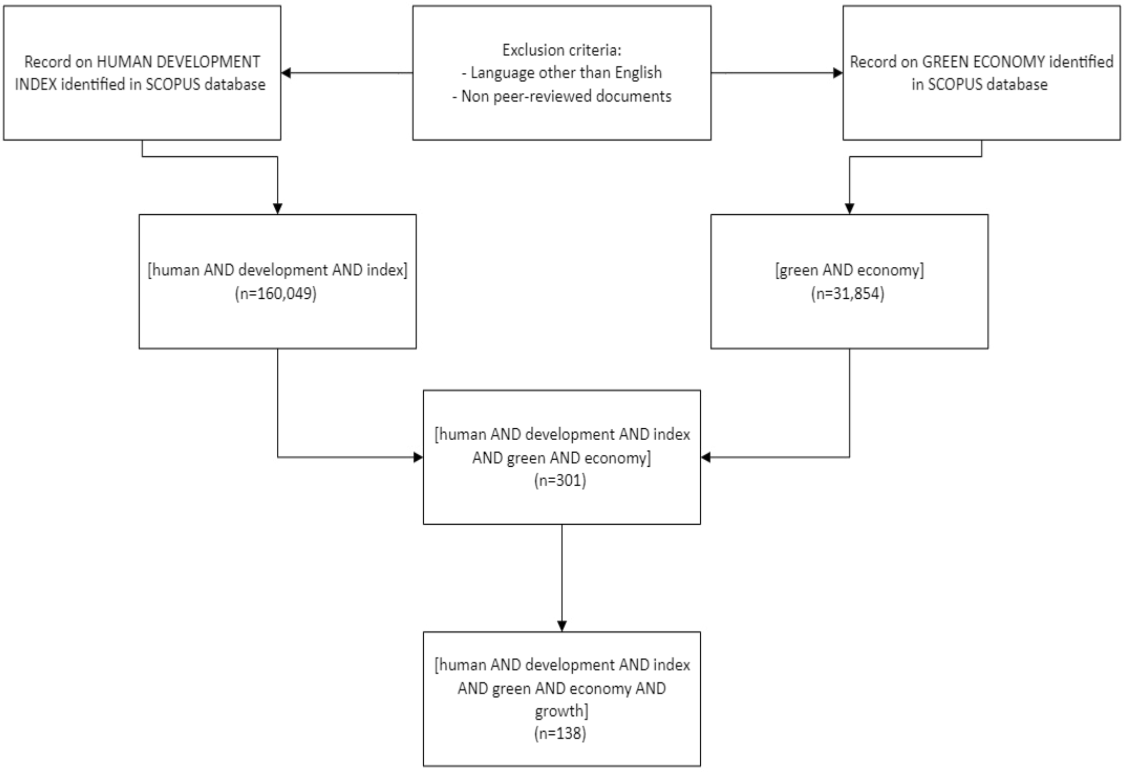


Figure 1. Selection of sources of parallel scoping reviews on the potential relationship between HDI and green economy

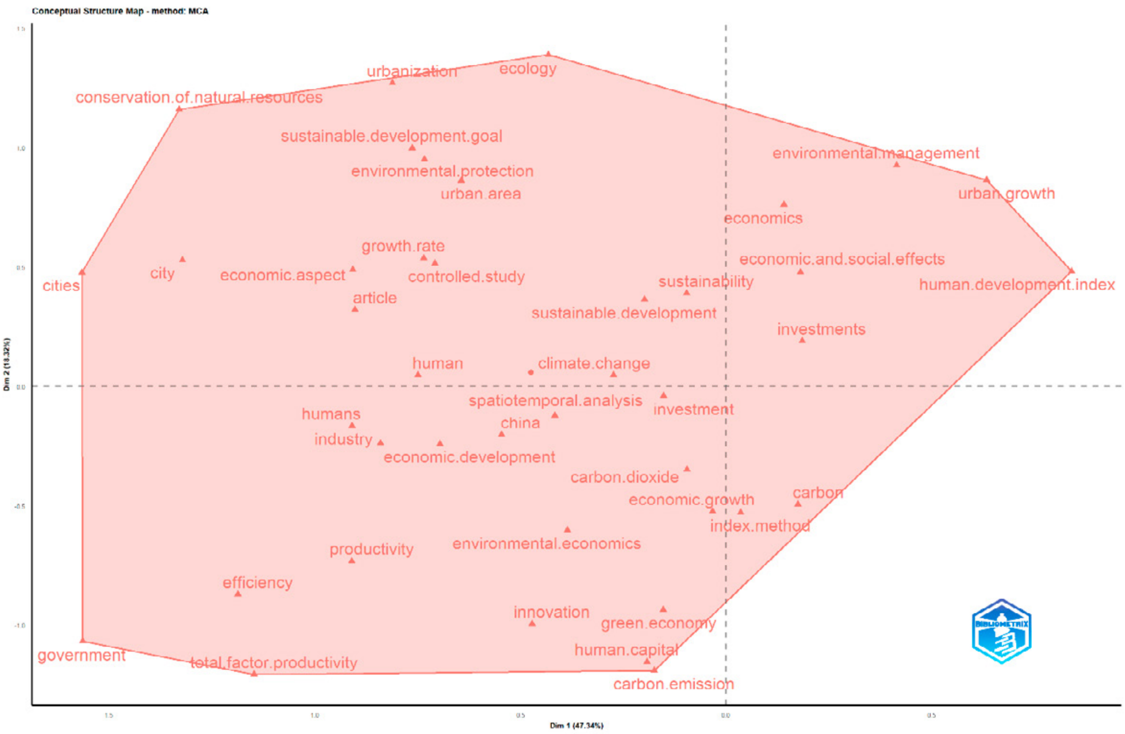


Figure 2. Words combination for analysed keywords

Source: authors' work with using Bibliometrix tool.

Two areas of literature review are highlighted: (1) "Human Development Index" and (2) "green economy". Both were subjected to bibliographic analysis using the Bibliometrix programme. The application was built in R (a programming language supported by the R Core Team and the R Foundation for Statistical Computing). In the case of the former ("Human Development Index"), 160,049 articles dating back to 1911 were found. For the second area (green economy), 31,854 articles dating back to 1930 were found. From such areas, publications related to both of them ["human AND development AND index AND green AND economy"] were selected for analysis, narrowing the area down to 301 publications. A further refinement of the criteria ["human AND development AND index AND green AND economy AND growth"] identified in final 138 publications (Figures 2).

Articles in the searched range dated back to 2013. The largest increase in articles was recorded between 2019 and 2020 and from 2022 onwards (around 30 per year). Scientific articles predominated among the publications (108). Other publication types were books (4) or chapters in them (5) or conference papers (8) or peer-reviewed papers (2). Among the most common words were: *China* (127 times), *economic development* (79 times) and *sustainable development* (63 times). *Green economy* was used 25 times and *human development index* 14 times. The used words allows to categorise the statements into 5 clusters: (1) *economic aspect*, (2) *carbon*, (3) *review*, (4) *China* and (5) *strategic approach* (Figure 3).

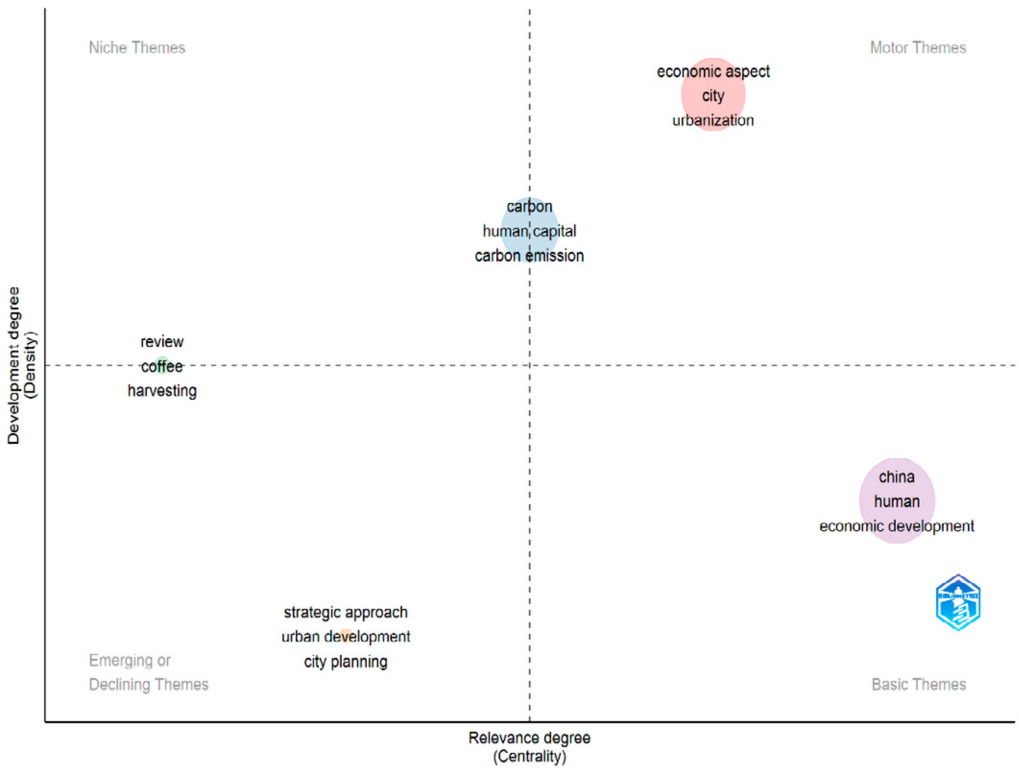


Figure 3. Clusters of words combination for analysed keywords

Source: authors' work with using Bibliometrix tool.

An analysis of publication trends showed that since 2013, the topics have changed, moving from issues related with *human development index* concept, *decision making* and *planning* through *urban areas*, *China* and *sustainable development* to *climate change*, *economic development* and *economic growth* (Figure 4).

The articles that linked the issues studied, i.e. the HDI and the green economy and green growth, highlighted the difficulty of analysing these phenomena in depth, due to the generic nature of some of the indicators commonly used (e.g. HDI, Index of Sustainable Economic Welfare – ISEW, Genuine Savings Index – GSI, Environmental Sustainability Index – ESI, Environmental Performance Index – EPI, Inclusive Wealth Index – IWI, Sustainable Society Index – SSI) (Baral & Holmgren, 2015).

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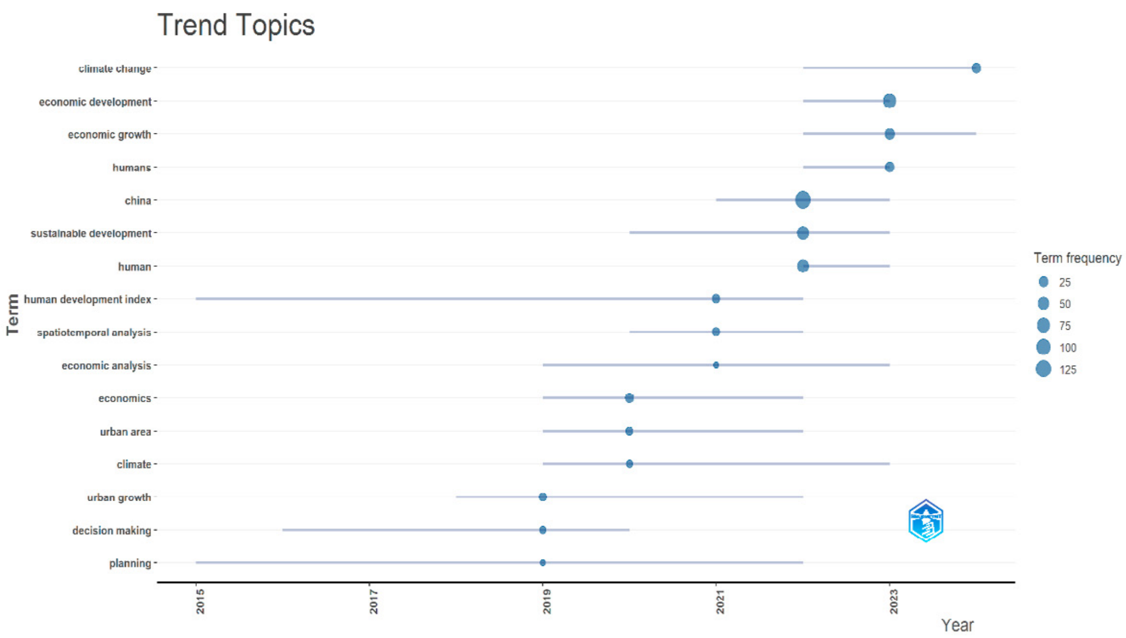


Figure 4. Publication trends in relation to the analysed keywords

Source: authors' work with using Bibliometrix tool.

These difficulties also arise from the content of the indicator in question, for example, energy consumption, which is explicitly linked to the dynamics of economic development. As the authors of one study point out, "Energy consumption (EC) can be seen as a two-edged sword. It can be not only essential for sustaining good standards of living but also in hindering environmental protection" (Sanchez-Loor & Chang, 2013). Therefore, attempts are being made to operationalise an index that combines the two issues analysed, such as the Inclusive Green Growth Index (IGGI), which combines the economic, social and environmental spheres and is based on 28 specific indicators (i.a.: per capita GDP, per capita disposable income of urban residents, digital economy index, ratio of students in primary schools, number of medical institutions, industrial wastewater discharge per GDP or energy consumption per capita) (Fan et al., 2023). An indicator of a similar nature is the Integrated Resource Efficiency Index (IRE-Index), which combines social and economic measures derived from the HDI with measures of material, energy and carbon productivity, estimated in terms of economic resource capital or units of resources produced or consumed per US$1 of GDP (Koh et al., 2016). The study that has attempted to develop a measure that combines issues of inclusive green growth with inclusive socio-economic development is that proposed by Satrianto and Juniardi (2023), where inclusive green growth is a combination of two development concepts (i.e. green growth – GG and inclusive growth – IG). These authors point to the close relationship between the concepts of inclusive green growth and inclusive social development. They point out that "inclusive green growth is a function of inclusive human development, regional financial performance and industrialisation" (Satrianto & Juniardi, 2023), while "inclusive human development is a function of inclusive green growth, natural disasters and democracy" (Satrianto & Juniardi, 2023). The results of this research suggest that inclusive social development and regional financial performance have a positive impact on growth, while industrialisation has a negative impact. Factors that have a positive impact on inclusive human development are inclusive green growth and democracy, while natural disasters do not have a significant impact. The results of other studies show that, at the macro level, the availability of clean energy or technological innovation has a positive impact on the HDI and urbanisation has a negative impact on its value (Gyamfi et al., 2024). Beyond this, it may be questioned whether well-being as measured by the HDI or its extended version (AHDI) is compatible with respect for environmental resources. Research to date has shown that "no country in the world has yet managed to achieve very high levels of human wellbeing within planetary boundaries" (Infante-Amate et al., 2024).

## Research methods

In the analysis carried out for the study, 16 of the 69 indicators included in the basic database proposed by the Statistics Poland were selected to define the green economy (GUS, 2022). However, not all measures are available, so from the four proposed areas:

1) natural capital,
2) environmental efficiency of production,
3) environmental quality of life of the population,
4) economic policies and their impacts,

those measures were selected that were available in the Statistics Poland database. They are presented in Table 2.

Table 2. Groups of indicators used in the study

| Groups of indicators | Overall name of the indicator | Specific indicators |
|---|---|---|
| Natural capital | Biodiversity | • Share of legally protected areas in the national territory [%] |
| | Land use | • Agricultural and forest land excluded for non-agricultural and non-forest purposes<br>• Degree of rehabilitation/development of devastated and degraded areas |
| | Forest resources | • Forest area<br>• Deforestation |
| | Freshwater resources | • Groundwater resources |
| Environmental production efficiency | Water management | • Water consumption for economy and population per capita<br>• Domestic water consumption |
| | Waste management | • Municipal waste collected per 1 inhabitant<br>• Share of recycled waste in total waste |
| Environmental quality of life of the population | Dust Air pollution | • National average exposure indicator for PM2.5 |
| | Access to drinking water | • Population using the water supply network |
| | Urban wastewater treatment | • Sewerage network<br>• Urban area |
| | Green spaces | • Green areas per 1 inhabitant |
| Economic policies and their implications | Organic farms | • Environmental services |
| | R&D activities | • Internal expenditure on R&D activities |

Indicators were chosen for the study so that they could be compared between provinces and were therefore converted to population or area. They were then subjected to a preliminary analysis (descriptive statistics) in order to eliminate characteristics with low variability and those that are too highly correlated with each other (correlation analysis). All data refer to 2022 and were the latest available at the time of writing.

To check whether the indicators show certain common features, a taxonomic method was used – cluster analysis. One of the agglomerative clustering methods was used – Ward's method. The method uses the variance analysis approach in its procedures (Grabiński, 1992). It aims to minimize the sum of the squared deviations of any two clusters that can be formed at any stage of the research. This is one of the most effective clustering methods. It allows the separation of groups of objects that are similar in terms of the factors (variables) analysed. Then, using a scree plot, it was determined that the clearest division of the cluster tree takes place in the case of division into four clusters. The order of procedure in Ward's method is similar to that in other agglomerative methods. Significant differences occur in the parameters used in the formula. The scheme of the procedure is as follows: it begins with determining the matrix of taxonomic distances with dimensions $n \times n$, which contains the distance of each pair of objects. The matrix is symmetrical with respect to the main diagonal, which is all zeros. Then, pairs of objects (and later clusters) are found for which the mutual distance is the smallest. Objects are marked as "*p*" and "*q*", where $p < q$. Then, "*p*" and "*q*" are combined into one new cluster, which occupies the position with the number "*p*". At the same time, the object (cluster) with the number "*q*" is removed, and the numbers of clusters with a number higher than it are reduced by one. In this way, the dimension of the matrix is reduced by 1. Then, the distance of the new cluster from each of the remaining ones is determined according to the formula:

$$D_{pr} = a_1 \cdot d_{pr} + a_2 \cdot d_{qr} + b \cdot d_{pq}, \tag{1}$$

where:
$D_{pr}$ – distance of the new cluster from the cluster with the number "*r*",
$d_{pr}$ – distance of the original cluster "*p*" from the cluster "*r*",
$d_{qr}$ – distance of the original cluster "*q*" from the cluster "*r*",
$d_{pq}$ – mutual distance of the original clusters "*p*" and "*q*",
$a_1$ ,$a_2$ ,b – parameters which are calculated in Ward's method based on the following formulas:

$$a_1 = \frac{n_p+n_r}{n_p+n_q+n_r}, a_2 = \frac{n_q+n_r}{n_p+n_q+n_r}, b = \frac{-n_r}{n_p+n_q+n_r}. \tag{2}$$

$n_p$, $n_q$, $n_r$ – indicate the numbers of individual objects in particular groups.

For the obtained clusters, the group average analysis was performed, which aims to indicate the indicators (diagnostic features) dominant in a given group. For the numerical data matrix, the general arithmetic means (without division into groups) of the studied indicators were calculated, denoted by. Then, the group arithmetic means of the studied indicators in the obtained clusters were calculated and marked as . The indicator of the structure of each cluster is the quotient $\overline{w}_i/\overline{W}_i$ . High values of the mean structure index indicate the dominance of a given feature in the obtained group. If the average level of a phenomenon in a group is identical to its average level in the entire studied population of objects, the mean ratio takes the value of 1 (or 100%). Values above 1 (>100%) indicate an average level of the factor in the group significantly exceeding its general average, and values below 1 (<100%) indicate a lower average level of this factor in the studied group in relation to the entire analysed population.

To check whether there is a relationship between individual clusters and the level of the HDI index, the nonparametric Kruskal-Wallis H test was used. The research was conducted at a significance level of α=0.05.

## Results of the research

The basic descriptive statistics of the selected indicators are presented in Table 4 (the colours in the table correspond to the different areas of the green economy).

The set of green economy indicators responsible for **natural capital** included six measures. The share of legally protected areas in the national area is given as a percentage. The average for all regions was 33.29%. The lowest share was recorded in Dolnośląskie Province (18.6%) and the highest in Świętokrzyskie Province (64.9%). The skewness shows that in the majority of the provinces, the share of protected areas was less than 33.3%. Agricultural and forest land set aside for non-agricultural and non-forest purposes per 10,000 ha is the second indicator characterising the green economy. On average, there are 1.74 ha of such areas per region. The largest is in the Pomorskie Province (4.28 ha) and the smallest in the Kujawsko-Pomorskie Province (0.39 ha). The skewness shows that in most of the provinces surveyed, the amount of agricultural and forestry land used for non-agricultural and non-forest purposes per 20,000 hectares is lower than the average of 1.74 hectares. The third indicator analysed was the level of rehabilitation/development of degraded land per 10,000 hectares. The average is 1.1 ha per 10,000 ha. Łódzkie Province has the highest rate of recultivation (3.89 ha), while Zachodniopomorskie Province has the lowest (0.23 ha). The skewness shows that in most provinces, the level of rehabilitation/development of degraded land per 10,000 hectares was lower than the average for all provinces (1.1 hectares).

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Table 4. Basic descriptive statistics of green economy indicators

| No. | Indicator | Mean | Me | Min | Max | Std. Dev. | Coef. Var. | S | K |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Percentage of national territory protected by law | 33.29 | 30.35 | 18.60 | 64.90 | 13.14 | 39.48 | 1.10 | 0.76 |
| 2 | Agricultural and forest land set aside for non-agricultural and non-forest purposes per 10,000 ha | 1.74 | 1.79 | 0.39 | 4.28 | 1.02 | 58.73 | 0.85 | 1.00 |
| 3 | Degree of rehabilitation /development of blasted and degraded land per 10,000 ha | 1.10 | 0.73 | 0.23 | 3.89 | 0.96 | 87.18 | 1.84 | 3.80 |
| 4 | Forest area as % of land area | 31.69 | 30.05 | 22.00 | 51.70 | 7.70 | 24.30 | 1.14 | 1.63 |
| 5 | Timber harvest in $m^3$ per forest area in ha | 0.88 | 0.71 | 0.26 | 1.86 | 0.51 | 58.21 | 0.86 | -0.40 |
| 6 | Exploitable groundwater resources [$hm^3$] per 10,000 inhabitants | 6.02 | 5.02 | 2.14 | 17.95 | 3.98 | 66.19 | 2.00 | 4.89 |
| 7 | Water consumption for economy and population per capita [$m^3$] | 213.68 | 110.45 | 74.60 | 990.70 | 249.07 | 116.56 | 2.46 | 6.19 |
| 8 | Household water use [dam3] per 1,000 inhabitants | 33.62 | 34.08 | 24.81 | 40.19 | 4.33 | 12.89 | -0.29 | -0.45 |
| 9 | Municipal waste collected per capita [kg] | 208.18 | 213.60 | 131.10 | 259.80 | 37.28 | 17.91 | -0.52 | -0.02 |
| 10 | Share of waste recovered [%] | 20.43 | 17.15 | 2.20 | 54.90 | 15.02 | 73.51 | 0.77 | 0.06 |
| 11* | National average exposure indicator for PM2.5 | 15.36 | 15.50 | 11.50 | 20.25 | 2.44 | 15.88 | 0.26 | -0.31 |
| 12 | Water supply network in km per 100 $km^2$ | 109.72 | 103.10 | 54.90 | 199.40 | 38.08 | 34.70 | 0.65 | 0.56 |
| 13* | Sewerage network [km] per 100 $km^2$ | 61.21 | 53.15 | 19.10 | 146.50 | 35.30 | 57.66 | 1.33 | 1.19 |
| 14 | Urban green areas per capita [$m^2$] | 51.78 | 44.25 | 25.50 | 160.10 | 30.70 | 59.30 | 3.24 | 11.83 |
| 15 | Organic area as a percentage of agricultural area [%] | 0.23 | 0.18 | 0.05 | 0.61 | 0.16 | 72.24 | 1.10 | 0.46 |
| 16 | Internal R&D expenditure per capita | 900.01 | 650.65 | 238.00 | 2842.4 | 680.03 | 75.56 | 1.85 | 3.59 |

Note: * – excluded variable; Me – median; Min – minimum; Max – maximu; Std. Dev. – standard deviation; Coef. Var. – Coefficient of Variation; S – Skewness; K – Kurtosis.

The fourth variable is the percentage of the land area that is forested. On average, the province accounts for 31.69% of the total forest area. The highest share was recorded in Lubuskie Province (51.7%), and the lowest in Łódzkie Province (22%). The skewness shows that in most of the provinces studied, the share of forest area is lower than the average. Wood harvesting in $m^3$ per ha of forest area is the fifth green economy indicator in this group. The average value is 0.88 m3 per ha. The highest value of wood harvesting in $m^3$ per forest area is in the Zachodniopomorskie Province (1.86 $m^3$), the lowest in the Podlaskie Province (0.26 $m^3$). The skewness shows that in most provinces the felling per $m^3$ is lower than the average. The final indicator used in the study was exploitable groundwater resources (in $hm^3$) per 10,000 inhabitants. The average value for all the provinces surveyed was 6.02 $hm^3$ per 10,000 inhabitants. The lowest value was reached in Małopolskie Province, with only 2.14 $hm^3$ per 10,000 inhabitants, and the highest in Lubuskie Province, with 17.95 $hm^3$. The skewness indicates that the exploitable groundwater resources per 10,000 inhabitants are lower than the average in most of the provinces.

The group of green economy indicators responsible for **the environmental efficiency of production** included 4 measures. Water consumption per capita for the economy and population in $m^3$ is the water used to fill and refill fish ponds. Until 2018, this item included water used for the irrigation of agricultural and forestry land and for the filling and refilling of fish ponds. The area criterion

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for filling fish ponds is 10 ha or more. The average value of the indicator for the surveyed provinces was 213.68 $m^3$. The largest was recorded in the Świętokrzyskie Province (990.7 $m^3$) and the smallest in the Warminsko-Mazurskie Province (74.6 $m^3$). The skewness indicates that in most of the provinces studied, water consumption for the national economy and population was lower than the average. Household water consumption (in $dam^3$) per 1,000 inhabitants is another indicator included in environmental production efficiency. The average for all provinces was 33.62 $dam^3$. The lowest value was recorded in Podkarpackie Province (24.81 $dam^3$) and the highest in Wielkopolskie Province (40.19 $dam^3$). The skewness shows that in most provinces, household water consumption per 1,000 inhabitants was higher than the average. Another indicator is municipal waste collected per capita (in kg). These are estimates until 2022. From 2023 onwards, they are not comparable with previous years due to a change in the calculation method of the indicator – the share of waste going to landfill in the amount of mixed waste collected during the year. Mixed municipal waste is waste collected during the year, excluding waste collected selectively and separated from the dry fraction. On average, the provinces surveyed collected 208.18 kg of waste. The least waste per capita was disposed of in Lubelskie Province (131.1 kg) and the most in Dolnośląskie Province (259.8 kg). The skewness shows that in most of the provinces surveyed the amount of municipal waste disposed of in kg per capita was higher than the average. On the other hand, the average share of recycled waste (in %) for all regions was 20.43%. Entities that generate more than 1,000 tonnes of waste (excluding municipal waste) in total in a single municipality during the year, or that accumulate 1 million tonnes or more of waste in their own landfills, underground waste impoundments, extractive waste facilities, including heaps and tailings ponds, are required to submit reports on this type of waste. The lowest value of this indicator was recorded in Lubelskie Province (2.2%) and the highest in Śląskie Province (54.9%). The asymmetry indicator shows that the share of recycled waste was lower than the average in most of the studied provinces.

The group of green economy indicators, which are responsible for the **environmental quality of life** of the population, included finaly two measures. The first indicator from this group (not removed from the final set of survey variables) was the water supply network in km per 100 $km^2$ of area. On average, the province has 109.72 km of water supply network per 100 $km^2$. The lowest indicator was found in Zachodniopomorskie Province (54.9 km) and the highest in Śląskie Province (199.4 km). The skewness shows that in most of the studied provinces the water supply network was smaller than the average. The second indicator in this group is the area of urban green spaces per capita in $m^2$. The average value was 51.78 $m^2$ per inhabitant. The smallest amount of urban green areas per inhabitant is found in the Mazowieckie Province (25.5 $m^2$) and the largest in the Podkarpackie Province (160.1 $m^2$). The skewness shows that in most of the provinces the area of urban green space per inhabitant was lower than the average.

The group of green economy indicators responsible for **economic policies and their impacts** was the smallest, with only two indicators. The first of these is the share of grassland in agricultural land. Its average value for all provinces was 0.23%. The lowest share of organic farmland in the agricultural area was found in the Świętokrzyskie Province (0.05%) and the highest in the Lubuskie Province (0.61%). The skewness shows that in most of the studied provinces, the share of ecological land in agricultural land was lower than the average. The last indicator considered in the study was internal expenditure on research and development (R&D) activities per capita. This is the expenditure incurred during the reference year on R&D performed within the reporting unit, irrespective of the source of the funds. It includes both current and capital expenditure on fixed assets related to R&D activities, but excludes depreciation of fixed assets. The average value of the indicator for all provinces was PLN 900 per capita. The highest R&D expenditure per capita was recorded in the Mazowieckie Province (2842.4 PLN), and the lowest in the Świętokrzyskie Province (238.0 PLN). The skewness shows that R&D expenditure per capita was lower than the average in most of the analysed provinces.

A correlation analysis was carried out on the variables selected to describe the state of the green economy (to check for high correlation) (Table 3).

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Table 3. Correlation matrix between study variables

| | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 | X15 | X16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X1 | 1.00 | | | | | | | | | | | | | | | |
| X2 | 0.01 | 1.00 | | | | | | | | | | | | | | |
| X3 | -0.34 | 0.14 | 1.00 | | | | | | | | | | | | | |
| X4 | 0.17 | 0.16 | -0.46 | 1.00 | | | | | | | | | | | | |
| X5 | -0.41 | -0.03 | -0.19 | 0.31 | 1.00 | | | | | | | | | | | |
| X6 | 0.08 | -0.51 | -0.11 | 0.46 | 0.03 | 1.00 | | | | | | | | | | |
| X7 | 0.41 | -0.01 | -0.28 | -0.12 | 0.03 | -0.18 | 1.00 | | | | | | | | | |
| X8 | -0.51 | -0.14 | 0.16 | -0.31 | 0.02 | 0.12 | -0.07 | 1.00 | | | | | | | | |
| X9 | -0.35 | -0.03 | -0.03 | 0.23 | 0.71 | 0.20 | 0.08 | 0.50 | 1.00 | | | | | | | |
| X10 | 0.24 | 0.12 | -0.36 | 0.28 | 0.12 | 0.01 | -0.07 | -0.31 | 0.05 | 1.00 | | | | | | |
| X11 | 0.11 | 0.08 | 0.24 | -0.48 | -0.01 | -0.55 | 0.05 | -0.18 | -0.05 | 0.40 | 1.00 | | | | | |
| X12 | 0.01 | 0.26 | 0.16 | -0.48 | -0.03 | -0.52 | 0.00 | -0.03 | -0.02 | 0.34 | 0.84 | 1.00 | | | | |
| X13 | 0.16 | 0.54 | -0.07 | 0.05 | 0.14 | -0.58 | -0.12 | -0.49 | -0.08 | 0.49 | 0.69 | 0.73 | 1.00 | | | |
| X14 | 0.19 | 0.25 | -0.08 | 0.43 | 0.05 | -0.12 | -0.20 | -0.56 | -0.24 | -0.19 | -0.11 | -0.19 | 0.35 | 1.00 | | |
| X15 | -0.22 | -0.25 | -0.25 | 0.61 | 0.52 | 0.65 | -0.17 | 0.06 | 0.44 | -0.23 | -0.70 | -0.55 | -0.38 | 0.15 | 1.00 | |
| X16 | -0.10 | 0.26 | 0.09 | -0.30 | -0.21 | -0.41 | -0.06 | 0.32 | 0.15 | -0.14 | 0.26 | 0.40 | 0.25 | -0.19 | -0.36 | 1.00 |

Based on the matrix of correlation coefficients, it can be concluded that no very high correlations were found between the potential variables adopted for the study. The highest correlation coefficient was 0.84, but this is an apparent correlation between the national average PM2.5 exposure indicator and the length of the sewerage network (in km) per 100 km$^2$ area. Therefore, both variables were excluded from the study.

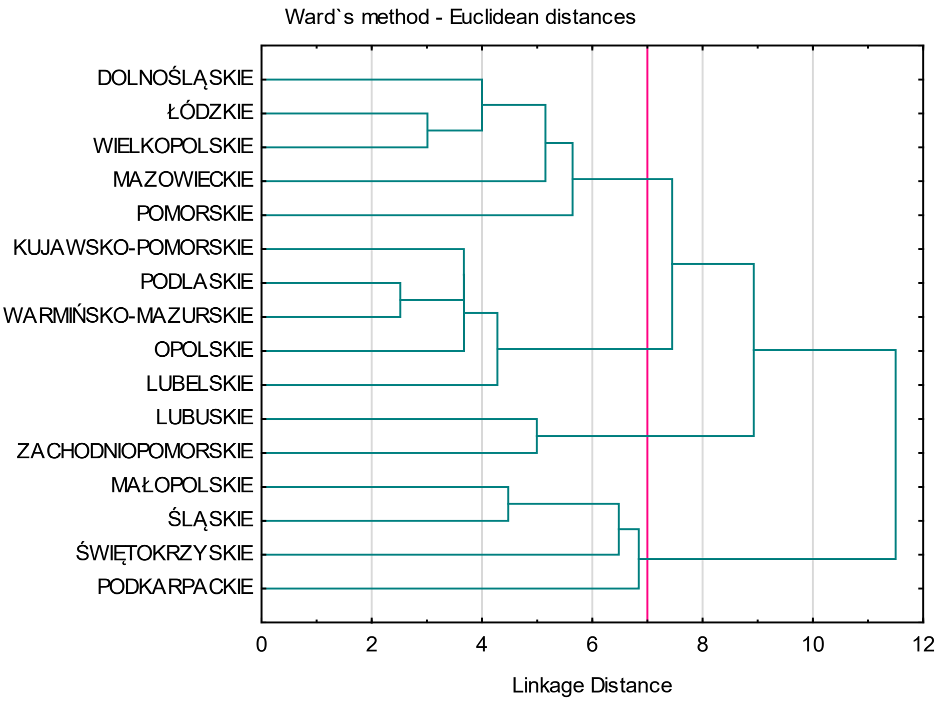


Figure 5. Results of clustering of provinces using Ward's method

Source: authors' work with using Statistica 13.3.

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In the second step of selecting the final set of variables, those whose coefficient of variation was >10% were selected for the dataset. In this case, this rule was met for all 14 variables.

On the basis of the characteristics chosen for the study, the provinces were grouped according to Ward's method, using the Euclidean distance (Figure 5).

As a result of the analyses carried out, 4 groups of provinces were distinguished, which were similar in terms of the characteristics responsible for the green economy (Figure 6):

- in the first group [a] – were the following provinces: Dolnośląskie, Łódzkie, Wielkopolskie, Mazowieckie and Pomorskie;
- in the second group [b] – the following provinces: Kujawsko-Pomorskie, Podlaskie, Warmińsko-Mazurskie, Opolskie and Lubelskie;
- in the third group [c] – there were two provinces: Lubuskie and Zachodniopomorskie;
- in the fourth group [d] – there were the following provinces: Małopolskie, Śląskie, Świętokrzyskie and Podkarpackie.

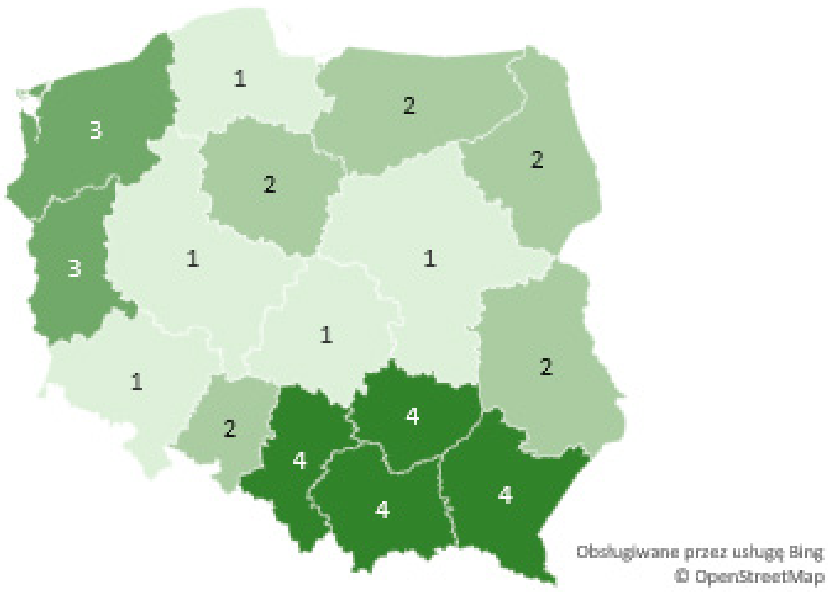


Figure 6. Division of provinces into 4 groups

Note: 1 – means group [a]; 2 – group [b]; 3- group [c] and 4 – group [d].

On the basis of the division introduced by the group averages, the resulting clusters were characterised. The resulting groups are very different in terms of the indicators used (Figure 7).

**Group [a]** consists of 5 provinces: Dolnośląskie, Łódzkie, Wielkopolskie, Pomorskie and Mazowieckie, which are characterised by **the lowest values** of the following indicators: the share of legally protected areas in the national area, the forest area as a percentage of the land area, the share of recycled waste (in %) and the area of urban green spaces per 1 inhabitant (in $m^2$). In this group, the indicators corresponding to the degree of reclamation/management of wasteland and degraded land per 10,000 ha, domestic water consumption ($dam^3$) per 1,000 inhabitants and internal expenditure on R&D activities per 1 inhabitant have **the highest values.**

**Group [b]** also includes 5 provinces: Kujawsko-Pomorskie, Podlaskie, Warmińsko-Mazurskie, Opolskie and Lubelskie, which can be considered as the worst cluster. None of the indicators analysed have the highest values compared to the other groups, but five have **the lowest values** (which does not mean that they are the worst). These are: agricultural and forest land used for non-agricultural and non-forest purposes per 10,000 ha, forest area as a percentage of the land area, timber harvest in $m^3$ per ha of forest, groundwater resources ($hm^3$) per 10,000 inhabitants and urban green areas per inhabitant (in $m^2$).

**Group [c]** contains only two provinces: Lubuskie and Zachodniopomorskie. Here, **the highest values** are recorded for the following indicators: forest area as a percentage of the land area, timber harvest in $m^3$ per hectare of forest, exploitable groundwater resources (in $hm^3$) per 10,000 inhabitants, municipal waste collected per inhabitant (in kg) and ecological area as a percentage of agricultural area. **The lowest values** of the group averages compared to the other groups are characterised by: the degree of reclamation/development of degraded and wasteland per 10,000 ha, the water supply network in km per 100 km$^2$ and the internal expenditure on R&D activities per capita.

The last **group [d]** consists of 4 provinces: Małopolskie, Śląskie, Świętokrzyskie and Podkarpackie, which can be considered as the best in terms of the examined green economy indicators. As many as 6 indicators have **the highest values** in relation to the other groups: share of legally protected areas in the territory of the country, agricultural and forest areas excluded for non-agricultural and non-forest purposes per 10,000 ha, water consumption for the needs of the national economy and population per 1 inhabitant (in m$^3$), share of recycled waste (in %), water supply network in km per 100 km$^2$, area of urban green spaces per capita (in m$^2$). The indicators with **the lowest values** are: exploitable groundwater resources (in hm$^3$) per 10,000 inhabitants, household water consumption (in dam$^3$) per 1,000 inhabitants, municipal waste collected per 1 inhabitant (in kg) and ecological area as % of agricultural area.

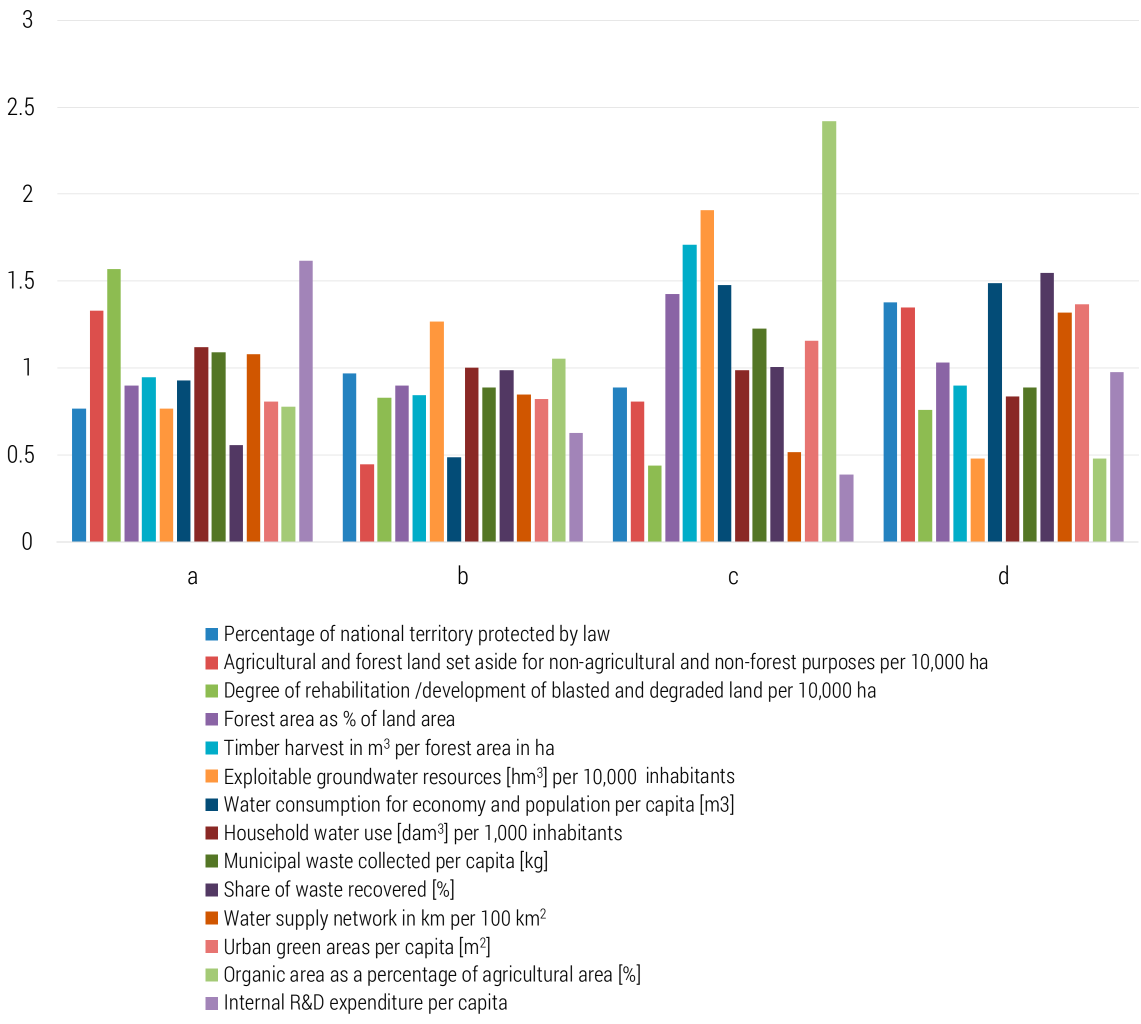


Figure 7. Group averages of indicators in each cluster

In the study, the green economy indicators were clustered with the HDI measure to examine the variation in the state of the green economy across provinces in relation to the Human Development Index. After clustering, the study examined whether there was a correlation between the resulting clusters and the HDI (Figure 8).

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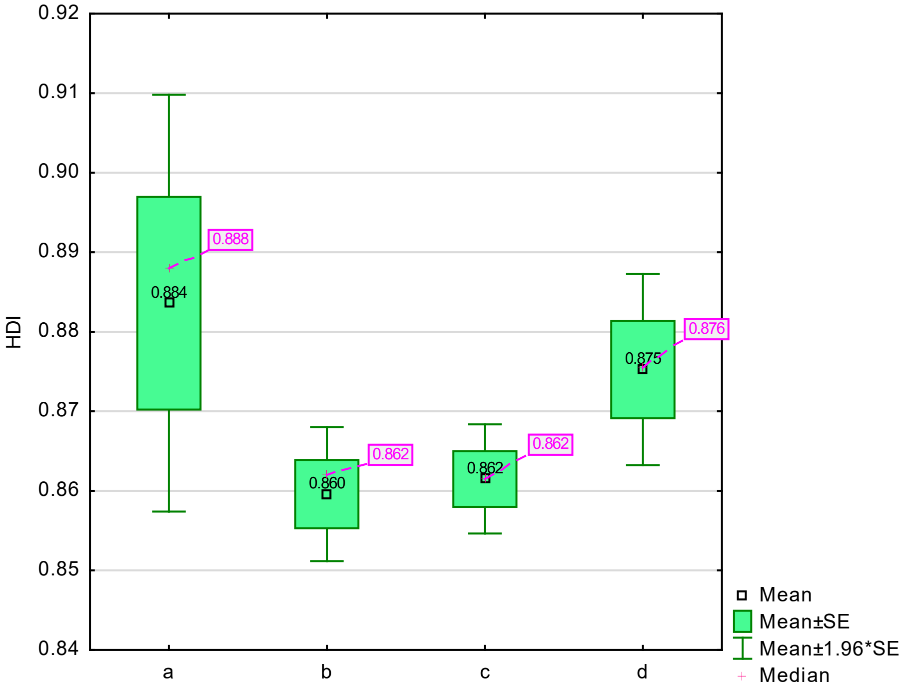


Figure 8. Summary of HDI levels in the resulting clusters

The non-parametric Kruskal-Wallis H test was used to compare the state of the green economy with the HDI. The analyses showed that $p>\alpha$ ($p$=0.0852). The test probability is greater than 0.05, so there were no statistically significant differences in the magnitude of the HDI index, but the test probability level is only slightly greater than $\alpha$=0.05, so the value of the HDI index in the different groups was checked. The results are shown in Figure 8. The highest HDI index was recorded in group [a], which included the following provinces: Dolnośląskie, Łódzkie, Wielkopolskie, Mazowieckie and Pomorskie, and the lowest in group [b], which included the following provinces: Kujawsko-Pomorskie, Podlaskie, Warmińsko-Mazurskie, Opolskie and Lubelskie.

## Discussion

When analysing the state of the green economy in Polish provinces, they were grouped, and the resulting clusters were characterised. In each group, there were indicators with the lowest or highest values. The lowest, which does not mean the worst, and the highest, which does not mean the best, from the point of view of the criteria for assessing the state of the green economy, as the analysed characteristics could be either stimulating or destimulating.

First, the clusters with the most indicators were analysed – these were group [d], which contained as many as 12 characteristics that positively or negatively described the state of the green economy, and group [c], which contained 10 such characteristics. In the end, it turned out that in group [d] there were 7 indicators that described the green economy positively and 5 negatively. In group [c], on the other hand, there were only 4 positive and 6 negative indicators describing the state of the green economy. Thus, the state of the green economy is better in the provinces of group [d] (Małopolskie, Śląskie, Świętokrzyskie and Podkarpackie Province) than in group [c] (Lubuskie and Zachodniopomorskie Province).

The other two clusters, [a] and [b], had the lowest number of maximum and minimum indicators (7 and 5 respectively). A closer look at these clusters reveals that cluster [a] is by far the worst, as most of the indicators analysed there show worse values in relation to the analysis of the state of the green economy.

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One of the aims of the study was to compare the state of the green economy in each group of provinces with the HDI indicator. It turned out that its level in the studied clusters was not significantly differentiated $p>\alpha$ ($p$=0.0852). Its value was between 0.844 and 0.926, which does not indicate regional disparities. On average, the highest values of the HDI index were achieved by group [a] (provinces: Dolnośląskie, Łódzkie, Wielkopolskie, Mazowieckie and Pomorskie), which, however, performs the worst in terms of the state of the green economy.

This cluster had the largest variation in the HDI index, ranging from 0.844 to 0.926. On average, cluster [b] (provinces: Kujawsko-Pomorskie, Podlaskie, Warmińsko-Mazurskie, Opolskie and Lubelskie) achieved the lowest values of the HDI index, which was only slightly better than the worst group in terms of the state of the green economy. However, this group is fairly homogeneous in terms of HDI, which ranged from 0.844 to 0.869 (Figure 8).

The research carried out allowed for the formulation of answers to the research questions – the main and the detailed ones:

- the state of the green economy in individual provinces is strongly diversified [Q1],
- there are provinces with a similar state of the green economy; 4 groups of provinces were created [Q2],
- the socio-economic development index is not related to the level of the green economy [the main research problem].

The value of each scientific study is the discussion in which the results obtained in the course of the research are compared with similar studies conducted by other scientists. Referring to the studies on the level of the green economy, it can be stated that different Authors:

1) use various sets of indicators to measure it (Szyja, 2014; GUS, 2023; GUS, 2022; Juszczak & Rabiega, 2021; Mihai et al., 2021; PAGE, 2017),
2) analyse its relationship, for example, with the concept of corporate social responsibility (Sulich, 2018), and examine its impact on education, health, employment, and quality of life (Stukalo & Simakhova, 2019).

In turn, studies on the level of social development refer to countries, regions, voivodeships (Migała-Warchoł, 2021; Migała-Warchoł & Szczygieł, 2018; Dąbrowa, 2018; Almoudi & Bafail, 2023; Hozer-Koćmiel, 2018). However, no studies were found that would directly refer to the concept included in the study, which would compare the level of the green economy with the HDI index.

## Conclusions

The green economy is a very difficult phenomenon to measure and analyse. A wide variety of indicators are used to measure it. The study is based finally on 16 of the 69 indicators proposed by Statistics Poland. They were characterised using basic descriptive statistics. It was checked whether they were characterised by high variability and whether they were too strongly correlated with each other (correlation analysis). In order to learn more about the diversification of the state of the green economy in individual Polish provinces, a cluster analysis was carried out, which made it possible to separate regions that are similar in terms of green economy characteristics. As a result of the applied procedure, 4 clusters were created. From the point of view of the green economy, the best group is cluster [d] (Małopolskie, Śląskie, Świętokrzyskie and Podkarpackie Province) and the worst is cluster [a] (Dolnośląskie, Łódzkie, Wielkopolskie, Mazowieckie and Pomorskie Province). The study compared the resulting clusters with the HDI index. On this basis, conclusions have been drawn on the relationship between the HDI and the level of the green economy in individual groups of provinces in Poland. However, it is not possible to make a clear assessment of the relationship between the green economy and the HDI, because cluster [d], with a high level of green economy, also had a relatively high level of HDI, while cluster [a], with the worst level of green economy, had the highest level of HDI. The analysis carried out only provides a diagnosis of the state of the green economy and the HDI, but does not give a clear answer as to why this is the case, so further in-depth research is needed. Their results would be very valuable for politicians and decision-makers making decisions regarding the level of development of the green economy in individual EU countries or regions.

The biggest research problem in studies based on such a large set of data is always the availability of up-to-date information. Often, the most available information refers to about two years ago. This was also the case here. An attempt was made to obtain as much data as possible. Ultimately, the study was based on 16 measures. Paradoxically, during the analysis, it turned out that with such a large number of variables, the results obtained were not unambiguous, because – the more indicators are studied (often in very different areas), the more dispersed the results are and the more difficult it is to draw unambiguous conclusions and compare them with other studies. Nevertheless, there is a need for further research, but based on a smaller set of diagnostic features regarding the selected area of the green economy, e.g. the environment. This would allow for a more detailed analysis, although with reference to a smaller scope of research.

### The contribution of the authors

Conceptualisation, T.P., K.Ch.-L. and E.S.; literature review, T.P. and E.S.; methodology, T.P. and K.Ch.-L.; formal analysis, R.P. and E.S.; writing, T.P., K.Ch.-L., E.S. and R.P.; conclusions and discussion, T.P., K.Ch.-L., E.S. and R.P.

The authors have read and agreed to the published version of the manuscript.

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# WSKAŹNIK ZIELONEJ GOSPODARKI A POZIOM ROZWOJU SPOŁECZNO-GOSPODARCZEGO – POMIAR I IMPLIKACJE NA POZIOMIE WOJEWÓDZTW

STRESZCZENIE: Przedmiotem opracowania były zagadnienia związane z zieloną gospodarką i wskaźnikiem rozwoju społecznego (HDI). Jego celem było sprawdzenie, czy występuje zróżnicowanie w poziomie zielonej gospodarki w badanych województwach oraz wskazanie powiązań między poziomem zielonej gospodarki a wskaźnikiem HDI. Główny problem badawczy sformułowany w formie pytania badawczego brzmiał: Czy poziom zielonej gospodarki jest powiązany ze wskaźnikiem rozwoju społecznego? W pierwszym etapie procesu badawczego określono poziom zielonej gospodarki w ujęciu regionalnym. Oparto się na najbardziej aktualnych dostępnych danych. Dotyczyły one roku 2022 i pochodziły z bazy danych Głównego Urzędu Statystycznego. Wybrano 16 z 69 miar zawartych w bazie. W kolejnym etapie wyniki uzyskane podczas grupowania porównano ze wskaźnikiem rozwoju społecznego. W badaniu wykorzystano analizę korelacyjną, taksonomiczną metodę grupowania obiektów – metodę Warda oraz nieparametryczny test H Kruskala-Wallisa. Grupowanie pozwoliło zdiagnozować stopień zróżnicowania zielonej gospodarki w województwach i utworzyć skupiska podobnych województw pod względem poziomu zielonej gospodarki. Test H Kruskala-Wallisa pozwolił sprawdzić, czy poziom zielonej gospodarki jest powiązany z HDI. W wyniku tych działań porównano uzyskane skupiska i sformułowano wnioski. Analizy wykazały, że poziom zielonej gospodarki istotnie różni się między województwami. Nie stwierdzono jednak statystycznie istotnej korelacji między poziomem zielonej gospodarki a wskaźnikiem HDI.

SŁOWA KLUCZOWE: zielona gospodarka, wskaźnik rozwoju społeczno-gospodarczego, analiza klastrowa, Polska, województwa

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