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Digital Futures

Indicators Monitoring the Relationship Between Environmental Sustainability and Future Readiness

Executive Summary

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Indicators Monitoring the Relationship Between Environmental Sustainability and Future Readiness – Executive Summary

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Sustainable development is now almost the only morally acceptable way into the future, following the slow theoretical change of direction of the past four decades. The social and economic limits set by the environmental subsystem can be pushed further by processes that increase the efficiency of human activity and conserve natural resources. Within this framework, the key factors that support future potential must be found. Measurement is a fundamental need for development and adaptation to changing circumstances. Monitoring provides feedback on how well the goals are set in reality during the theoretically desirable journey. The main task of this study is to explore further research directions in the intersection of environmental sustainability and measurement systems. For this, it was necessary to find the points of connection between environmental sustainability and future readiness, and to examine how these appear in the chosen measurement systems.

1 Scope and method of the research

During the research, we are looking for an answer to whether we can talk about the evolution of the concepts of environmental sustainability, innovation and resilience.

In the exploratory study, the appearance of environmental sustainability in the two widely known innovation measurement systems, such as the European Innovation Scoreboard (EIS) (EC, 2024) and the Global Innovation Index (GII) (WIPO, 2024) shall be examined. On the other hand, narrowing down the measurement systems of sustainability to the environmental aspect, the appearance of the notion of innovation shall be spotted. Among the sustainability measurement systems, the UN's indicator system related to the Sustainable Development Goals (SDG) adopted in the Agenda 2030 resolution (UN, 2024) and Sustainable Development Report (formerly SDG Index and Dashboard) annotated by the Sustainable Development Solutions Network (SDSN) (Sachs et al., 2023) are subject to examination.

The chosen method of the research is the bibliometric analysis, during which we examine the connections between the two key areas, future readiness and environmental sustainability, looking for connections and their characteristics among the keywords of scientific publications.

2 Conceptual framework and related monitoring systems

Future readiness is determined by the pillars formed from the four basic areas of change (Szántó, 2018, Szántó et al., 2020) and the reactions to them. These are ecology and geopolitics, technology, socio-economics and culture. The natural environment therefore appears explicitly in the system of pillars: in the form of ecological/geopolitical changes, which cover the global balance, geographical location of natural resources and the resulting political changes, anthropogenic climate change, the preservation of biological diversity and the availability of natural resources. A study examined the innovation and design aspect (Pörzse et al., 2023) of the above pillars, thus for the ecological-geopolitical pillar eco- and energy innovation and design (EEI), furthermore the (non-eco and non-energy related) technological innovation and design (TI), the social and business model innovation and design (SBMI), and the cultural innovation and design (cultural and innovation design, CI). The bibliometric examination of the four areas of innovation and design came to the conclusion that two drivers of change can be identified that affect all areas: one is sustainable development, the other is transdisciplinary research, during which one scientific field creates a new one with examples, good practices, or other combinations taken from another. This validates the close relationship between sustainable development and innovation.

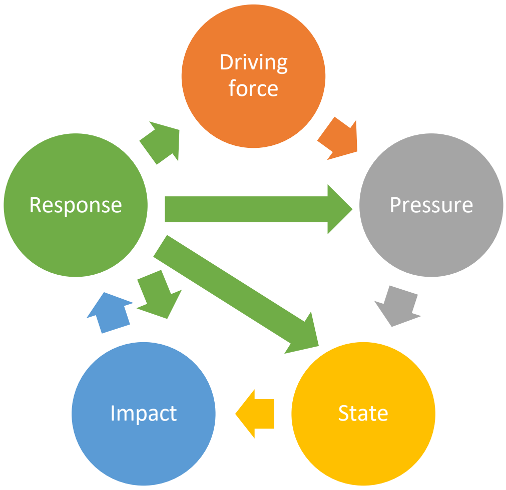
Moving on to the other conceptual field, we define sustainable development as follows: "...that meets the needs of the present without compromising the ability of future generations to meet their own needs." (WCED, 1987). As a result of the triple division of the Brundtland report – economy, society, environment – two parallel schools have emerged (Fleischer, 2014): weak sustainability depicts the set of three subsystems with common sections, which states that the capital of the three subsystems – natural, social and economic – cannot decrease overall. Strong sustainability depicts the subsystems in three concentric circles, the innermost being the economy, which is entirely embedded in the set of society, while the society is located in the outer set of the environment. This sequence states that the environment is the source of the other two systems, as well as the limiting factor. Decades after the Brundtland report, the Millennium Development Goals were set mainly to remedy the social problems of developing countries, and then the UN Agenda 2030 resolution was adopted in 2015, with which a system of 17 goals for sustainable development was created, one of which specifically focuses on innovation (SDG 9). The 169 targets were described with 244 indicators (231, if the so-called multi-purpose, i.e. indicators that occur more than once, are counted once). In this set of SDG goals the ones to be fulfilled by the developed states and the environmental aspects also became more prominent.

3 Theory of environmental indicators

The indicator is more complex than a simple indicator, because it represents a system of relationships: it presents a time series that either has a desirable development direction, or the indicator measures against a target number set by policy or by other circumstances (Massarelli et al., 2017; Havasi, 2007). The indicators are most suitable for broad public communication and for serving political decision-makers who are responsible for many areas of expertise and therefore do not have the capacity for a profound approach. Indicators are often aggregates or composite indicators formed from sub-indicators with a consistent methodology. Indicators aggregated to a high degree into a single data – for example at a level above dimensions –

are called indexes. Indicator systems provide a detailed overiew, indices provide rapid information (Eurostat, 2018).

Within the descriptive category, the model most often used in environmental assessment is the so-called DPSIR (Smeets et al. 1999).



1. Figure - The DPSIR model (Source: Smeets et al., 1999)

Based on the PSR (Pressure-State-Response) model created by the OECD in 1993 (OECD, 1993), the European Environmental Protection Agency built this expanded model in 1999, which is based on the interaction of human activity and the environment; it aims to map the environmental effects and the responses to them, in this sense, it can be an adequate process analysis tool for preparing for the future. In the study, the indicators of the examined measurement systems are classified based on the PSR model, also mentioning if indicators appear in the Driver or Impact categories.

4 Monitoring systems and their development

One of the two innovation measurement systems examined is regional: the European Innovation Scoreboard (EIS) is reported annually by the Commission of the European Union, which since 2001 measures the innovation performance of the member states of the European Union, and classifies them. The monitoring system contains 32 indicators classified into 12 dimensions, which cover 4 topics: framework conditions, investments, innovation activities and effects. The four topics contain the same number of indicators and are included in the composite Innovation Index with the same weight.

The development of the Global Innovation Index (GII) is linked to Dutta. The index defines innovation according to the Oslo Manual (OECD/Eurostat, 2018): “a new or improved product or process (or combination thereof) that differs significantly from the unit’s previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)”.

There are many problems in relation to the UN SDG indicators. First, such a quantity of indicators already has a significant impact on the transparency and interpretability of the indicator system (Biggeri et al., 2019). On the other hand, during the production of indicators, while economics and sociology are traditional fields in the national statistical offices, there is no capacity built for collecting environmental data, even in developed countries. The fact that the greater part of the indicator system in force is specifically designed to map the progress of developing countries is also a difficulty for developed countries. For this reason, a relatively common solution is to keep the goals and/or sub-goals and assign them a set of national indicators: indicators that are relevant in the context of the given state, that are adapted to local conditions, but this undoubtedly makes international comparability difficult (Graczka, 2023).

A typical point of conflict in the indicator development process was that the specialized agencies of the UN acting as so-called ‘custodian agencies’ of indicators often approach the measurement of a phenomenon on a theoretical level, while the signatory countries were more strongly data-driven, i.e. their main point is whether data is available, if not, how much additional capacity is required for production, and is it cost-effective. The monitoring development is proceeding extremely slowly due to the many actors involved. Since 2015, the list of indicators changed primarily due to a persistent lack of methodology and/or data.

The Sustainable Development Report is considered to be an alternative indicator system, which preserves the UN SDG goal system, but is prepared with a modified indicator list. In the selection of indicators, priority was given to the official indicators used by the United Nations Statistics Division (Lafortune et al., 2018). In cases where no methodology or data were available, substitute indicators were sought from other official or unofficial sources. The indicator list of the SDG Report is constantly subject to minor modifications, but at the same time it is characterized by environmental dominance based on the intensity map of Kocsis (Kocsis, 2020).

5 Indicators of monitoring systems linking environmental sustainability and innovation

Linkages of environmental sustainability and innovation were identified in the selected monitoring systems. In the indicator systems of the EIS and the GII environmental indicators were sought. In the case of the SDG and SDR indicators, after narrowing them down to the topic of environment, the goal was to identify the indicators that measure innovation. In both cases, the investigation also covers the evaluation of the indicators based on the factors of how appropriately the individual indicators describe the phenomena, and whether they are sufficiently comprehensive, and correspond to the ecological aspects of future readiness (Aczél, 2018).

European Innovation Scoreboard (EIS)

Among the indicators of the European Innovation Scoreboard, out of the four dimensions of Framework conditions, Investments, Innovation activities and Effects, the environment only appears explicitly among the Effects: environmental sustainability is an individual subsection here. The three indicators show large deviation in their comprehensive nature. Resource productivity is the quotient of GDP and domestic material consumption (DMC), showing the GDP production per unit of natural resources. This indicator is one of the most comprehensive environmental indicators because it examines the efficiency of human activity; they shed light on the innovation processes, in which the most important goal is to be able to decouple material consumption from GDP growth. The second indicator is the PM2.5 emissions of the manufacturing industry projected on gross value added (GVA), which represents a very small slice of emissions. The third environmental indicator is the development of environmental technologies which, based on the metadata, is the number of patents registered for environmental technology inventions as a proportion of all patents. Again, this is a relatively comprehensive indicator and a forward looking, good indicator of future readiness. Among the context indicators, the indicator of circular material use (circular material use rate) relates to waste by presenting the materials used by the economy (DMC) and the use of secondary raw materials recovered from waste. The eco-innovation index is also a context indicator, which gives a broad impression of environmental and innovation processes, as it is a highly aggregated composite indicator, the inclusion of which in another indicator system can greatly distort the results, since it can weight one topic multiple times.

The environmental indicators of the EIS mainly measure the environmental pressure in the DPSIR model. The number of patents can be considered as a response indicator.

Global Innovation Index (GII)

GII's environmental indicators represent weak sustainability and prioritize the economic aspect: in addition to the cost of photovoltaic energy and wind energy, they measure the price of electric batteries. Practically, all sub-indicators of the index primarily measure the distance from fossil energy, which makes the environmental aspect extremely biased.

In the case of country-level indicators, energy use also appears first, and GII remedies the lack of all other aspects by including the Environmental Performance Index (EPI) ranking, which mostly includes pressure and state sub-indicators. The risk posed by integrating aggregate indices in other indicator systems have been detailed above. According to DPSIR, all indicators of the GII are pressure indicators. The only response indicator is the number of certificates issued to organisations with an environmental management system.

Sustainable Development Goals indicators (SDG indicators)

Environment-related indicators appeared in 10 out of the 17 sustainable development goals, a total of 58 out of 248 can be classified here, although the boundaries between environment-society-economy is often not discrete. It should be highlighted that in the Industry, Innovation and Infrastructure Goal (Goal 9) the environmental aspect appears directly by an indicator: this is carbon-dioxide emissions as a proportion of gross value added. It should be noted, that there are indicators (9.5.1. R&D expenditure as a proportion of GDP, 9.5.2. Number of researchers per 1 million inhabitants) which are also relevant to eco-innovation, and appropriate disaggregations are available in the Member States of the European Union. The fact that the environmental education indicator was able to appear in the case of the educational goal (4.7.1) is also forward-looking from the point of view of future readiness.

Overall, out of the 248 indicators, only one indicator connects directly the topic of environment and innovation. Goal 9 of the SDG encourages innovation in addition to creating resilient infrastructures and promoting inclusive and sustainable industrialization. Of the 12 indicators appearing here, two refer to transport infrastructure, two refer to gross value added projected on GDP and employment, previously mentioned indicators monitor the increasing role of small-scale enterprises, and the previously mentioned ones refer to carbon-dioxide emissions per unit of added value, R&D expenditures and the number of researchers are measured. There are three political indicators, which specifically apply to developing or least developed countries.

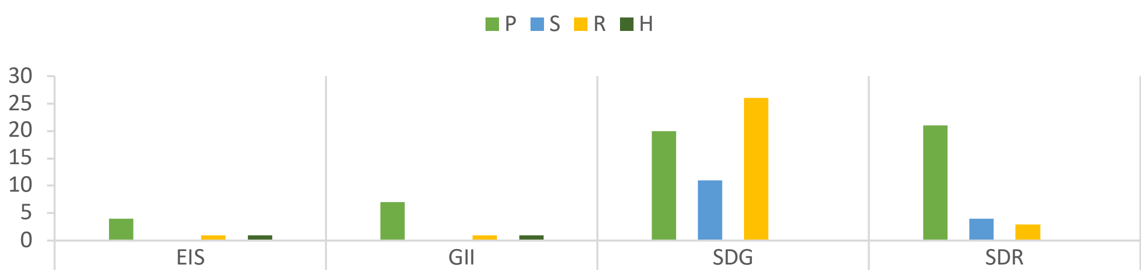
In a broader interpretation of future readiness, it is of great importance that, contrary to EIS and GII, the environmental SDG indicators show significant diversity in the PSR model. This heterogeneity of indicators capturing processes can significantly help in planning, in foresight, and thus also adaptation. The latter can be supported by the measures expected by the response indicators, if they turn into impact indicators instead of simple output indicators.

Sustainable Development Report (SDR)

The monitoring system of the SDR contains the same proportion of environmental indicators (23%) as the SDG, but the structure based on PSR is different. The absolute dominance of the pressure indicators can be observed in the SDR.

Regarding Goal 9 of the SDG, slightly different indicators were defined compared to the original system of the SDG indicators. In the innovation indicators, there is absolutely no intersection with the environmental topic. Innovation is measured by with the ranking of universities, the number of publications in scientific journals, the R&D expenditures proportional to GDP, the number of researchers per 1 million inhabitants, the number of triad patents, broken down to income categories and measured by internet access and the proportion of women obtaining tertiary degrees in STEM fields.

An alternative starting point for measuring environmental sustainability and preparing for the future is to use the PSR (Pressure – State – Response) or, for an even more sophisticated result, the DPSIR (Driving Force – Pressure – State – Impact – Response) model, which is otherwise widely used for environmental indicators. The steps of the processes described by the model reveal casual relationships. Therefore, if we understand what a typically economic-social driver can ultimately cause in the state of the environment, and what kind of response can be given to that, all three strategies outlined by Szántó (2018) will be feasible: the future-proof, the future-oriented and the adaptive strategy. The figure below shows which of the PSR phases are built into the monitoring systems through the indicators. The SDG stands out from other measuring systems with its many expected response indicators, although most of the response indicators refer to the existence of policy measures or documents that can be answered in a binary manner, but the impact is not captured, i.e. whether a national strategy or a signed international agreement is in practice what result it brings.



	EIS	GII	SDG	SDR
P	4	7	20	21
S	0	0	11	4
R	1	1	26	3
H	1	1	0	0

Figure 4 - The Pressure, State, Response type indicators that appear in the measuring systems. (H = hybrid, these cover the built-in composite indicators) (source: own compilation)

6 The relationship between monitoring systems and the scientific sphere

In the methodology of the examination of the connection, we look for the co-occurrences of the monitoring systems and the two aspects – i.e. environment in the case of the EIS and GII systems, and innovation and resilience in the case of the environmental SDG and SDR indicators – in a bibliometric study. The relationship was examined with the help of the three most well-known scientific search engines: we searched for results in the Web of Science, Scopus and Google Scholar databases, although the latter goes beyond the scope of peer-reviewed scientific publications. That is why Google Scholar outcomes are rather presented as a matter of curiosity.

This exploratory study relies on the keywords defined in the bibliometric research of Pörzse et al. (2023). Two of the four innovation driver pillars discussed earlier have a strong environmental focus. We linked their keywords with the AND Boolean operator to the names of the innovation monitoring systems. In the case of Eco- and Energy Innovation pillar: sustainable development, carbon dioxide, environmental policy, environmental impact; in case of Social and Business Model Innovation pillar, the co-occurrence of keywords sustainable development, environmental business models, sustainability, circular economy and sustainable business and the innovation monitoring systems (EIS and GII) were examined.

In case of sustainable development, the co-occurrence of the indicator systems (SDG, SDR) and the notions associated with future readiness, i.e. innovation and resilience were observed.

The examination of the EIS and the GII did not give assessable results, the SDG indicators and innovation/resilience were mentioned together in about 1,600-1,800 scientific publications, while the SDG Report itself was barely mentioned in the scientific journals, combining it with the notions of innovation/resilience there were no results.

7 Sustainable development and innovation measurements

None of the monitoring systems are relevant in the relationship between sustainable development and innovation. Probably due to their global nature and the number of indicators, the SDG indicators are the only ones that show such co-occurrences in the scientific literature. Of course, this does not mean that there is no other common denominator in terms of environmental sustainability, future readiness and monitoring, but the publications probably focus on other measurement methods. That is why the relationship between the three concepts of environmental sustainability, innovation/resilience and measurement/monitoring, as well as the number of mentions of them in scientific publications were observed more generally. During the bibliometric investigation, we mapped the co-occurrences of the 200 most relevant keywords in the scientific literature.

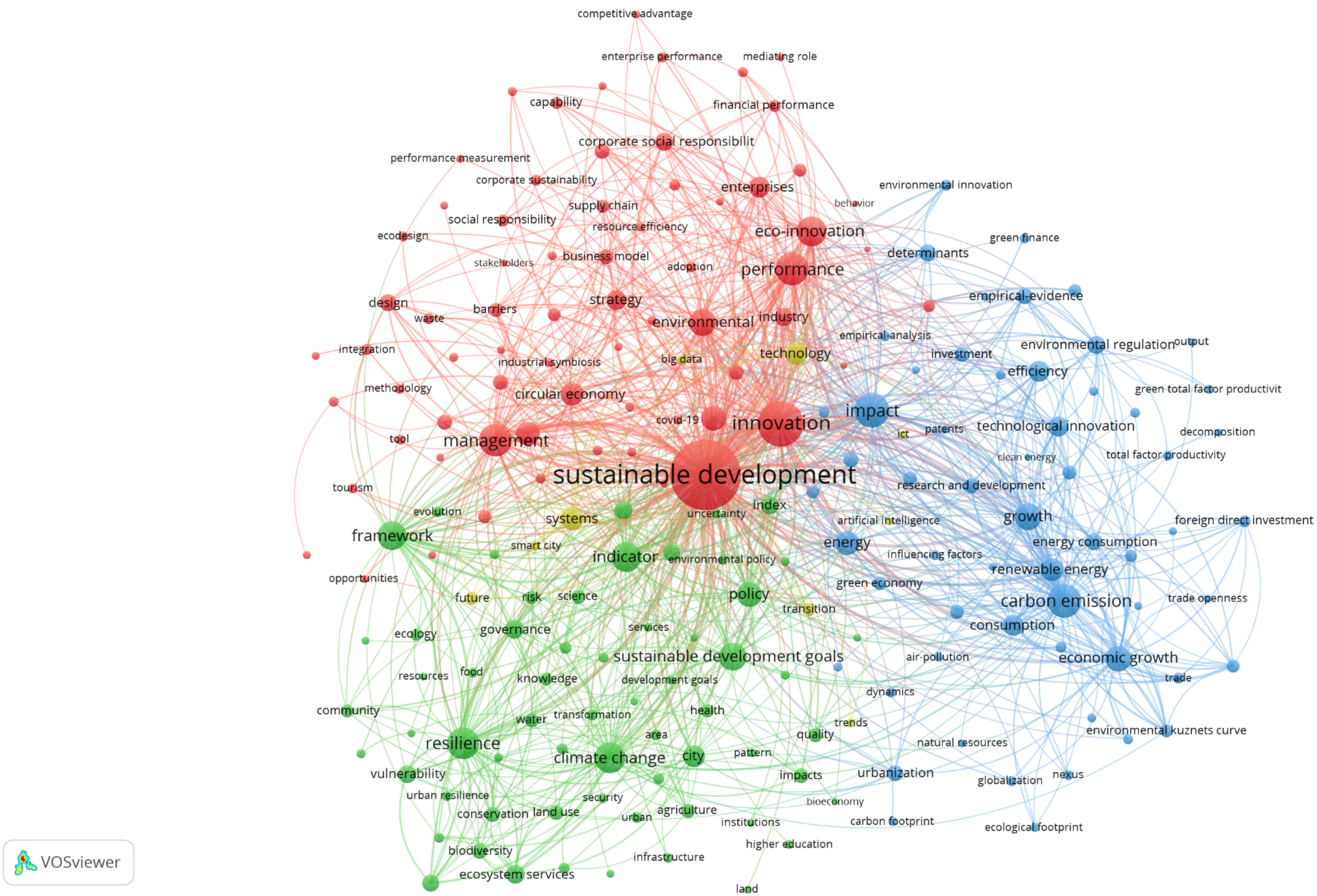


Figure 5 - Keyword clusters occurring in scientific publications (source: own compilation Vosviewer)

The "Sustainable business" cluster (red, n=69) includes the two most important keywords, sustainable development and innovation. The topics covered have a strong business focus, the economic aspect, sustainable corporate strategy, management and environmental performance are included here. Smaller groups within the cluster is the circular economy, innovation and eco-innovation. The term performance appears here in several forms (financial performance, environmental performance, enterprise performance).

The "Resilience" cluster (green, n=63) has a more general social character, where policy and governance come into play. Climate change is a central issue for these publications, as resilience appears primarily in this context in public communication. In connection with climate change, keywords related to the natural environment (e.g. ecosystem, biodiversity, green infrastructure) have been included. Keywords related to urban life, communities and human capital (health, education, poverty, knowledge) are emphasized in the cluster. The term indicator is placed in this cluster together with the goals of sustainable development, which indicates a broad discussion of sustainable development indicators at the level of individual countries, and that measurements are probably more important at the social and macro level.

The name "Sustainable technology" (blue, n=59) may be appropriate for the third cluster, and it refers to the authors' view that economic growth can be achieved by increasing efficiency and technological innovation, which appears as a strong driving force. The use of natural resources can be reduced by greening energy consumption and technological innovation. The discussion takes place within the traditional economic discourse along terms such as foreign direct investments and trade openness. Carbon emissions are probably important because the rationalization of energy consumption is a fundamental economic interest and reducing emissions is a positive externality of that.

The last cluster, on a relatively hidden layer, connected to each cluster in a relatively balanced way, was named "Sustainable system" (yellow, n=9), referring to the fact that such horizontal topics influence sustainable development and innovation, which are strongly connected to digitalization (AI, big data, ICT) and the systemic approach (transition, trend, system).

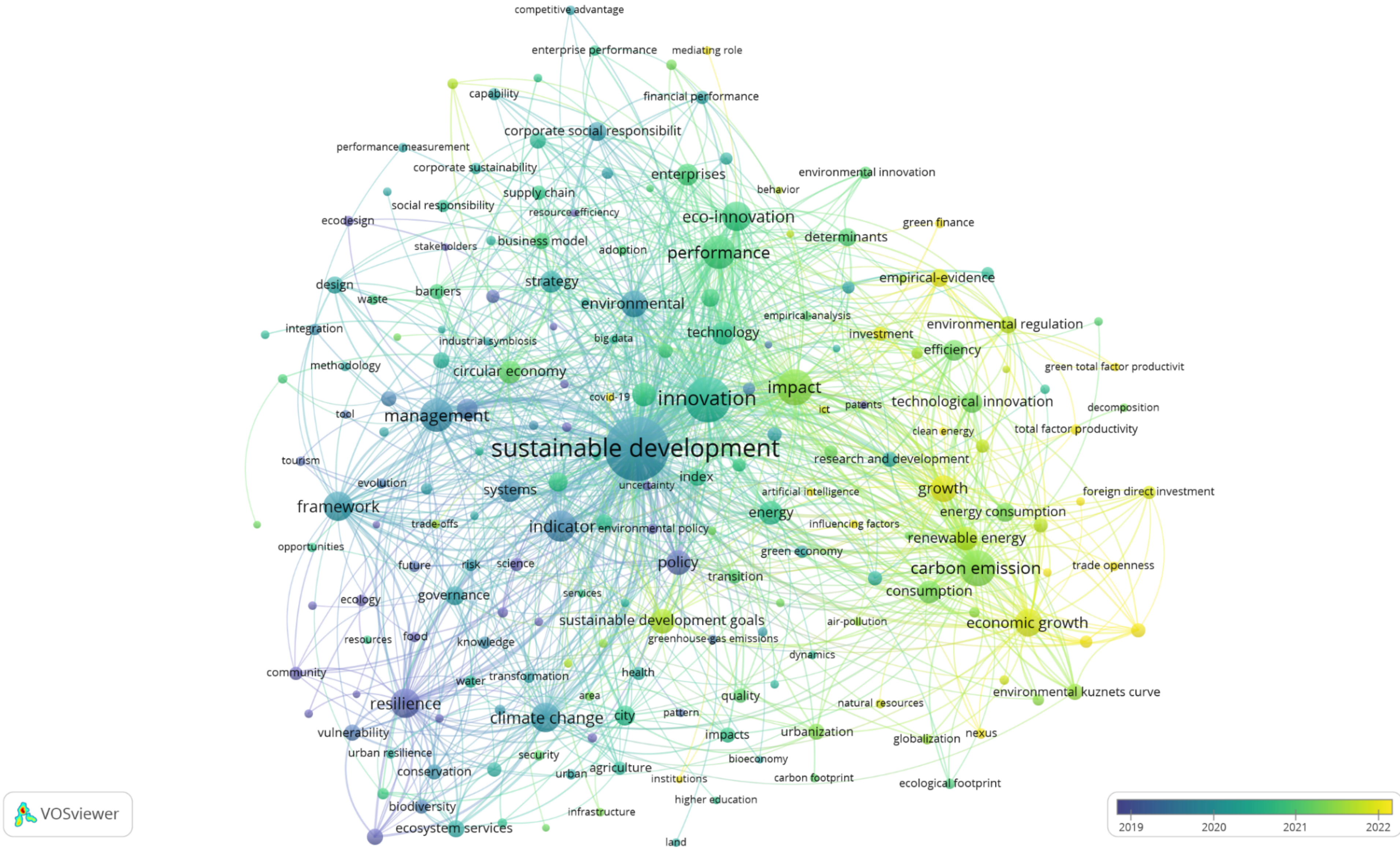


Figure 6 - Evolution of keywords grouped around sustainable development, innovation and resilience, and measurement (source: own compilation, Vosviewer)

We can find the imprint of global economic processes in the evolution of keywords over time. Around 2019, resilience, vulnerability and the policy level were at the forefront of academic interest. Around 2020, attention may have shifted to sustainable development and indicators on the one hand, and climate change on the other. The former could have come into focus because a comprehensive review of sustainable development indicators took place in 2020, offering the opportunity for amendments. Climate change may have become the focus of attention because the USA announced in 2019 that it would withdraw from the Paris Agreement, which stirred up the international scientific community. During the pandemic, the focus shifted to innovation and sustainable business processes. Presumably, in order to solve the new, never-before-experienced global problems – the difficulties arising from the shortage of raw materials, disruptions in supply chains, and business processes based on new remote work models – adaptation, innovation, and rethinking of business processes were necessary. The emerging energy crisis also contributed to shift with not only the transition to renewables, the rationalization of energy consumption, but also the reduction of carbon emissions. It was not by chance that expressions related to efficiency and technological innovation appeared on the map. The global economic downturn in 2020 and its consequences may have led to the fact that in 2022 scientific interest clearly turned towards the topic of economic growth, displacing the researched notions.

8 Conclusions, proposed directions for further research

In this study, the conceptual evolution of sustainable development was presented, on one hand, by a theoretical approach through a literature review, and also in the context of innovation/resilience and the indicators/monitoring. The latter was answered by bibliometric research showing how the focus of scientific publications has shifted in recent years.

The evolution of measurement systems were also discussed. In case of the SDG indicators – the only monitoring system showing relevant results – the development was pragmatic instead of tracking of scientific results, which reveals a contradiction in the relationship between policy and the scientific sphere: it seems that the motivation is completely different. In the case of the former, the goal is a rapid, timely, cost-effective mapping of reality, while the academics strives for well-founded theories not necessarily considering the lack of data as a strong limitation. Obviously, the development of the two areas may converge in the long term.

In the GII monitoring system, environmental sustainability appears as a biased focus on the decoupling from fossil energy carriers, while in the EIS monitoring system has incorporated more comprehensive indicators more effective in demonstrating future readiness. In the scientific publications, environmental sustainability and the mentioned two monitoring systems do not provide relevant number of results.

In the case of the UN SDG indicators, innovation is a relatively prominent topic, considering that Goal 9 of the SDG focuses on innovation, among others. At the same time, there was only one indicator for measuring the environmental aspects of innovation in the UN indicator system, while in the SDR system the two topics were not linked at all by indicators. Only the SDG indicator system shows relevant amount of co-occurrences with innovation in scientific publications.

Detached from the specific monitoring systems, the significance of the relationships between sustainability, innovation and resilience, and measurement and monitoring were tracked in general. The bibliometric research revealed that while the relationship (strength of links) between sustainable development and innovation is particularly close, i.e. they are mentioned together in a significant number of scientific publications, measurement and monitoring do not show such a close linkage, although this is also a determinant topic on the map. The fact that hardly any assessable results were found related to the selected monitoring systems, while the monitoring shows plenty of connections with the topics of environmental sustainability and innovation in general, suggests that other monitoring systems and models may be the subject of scientific publications.

Further research directions

The connection of the indicators to the term eco-innovation seems to be an interesting thread. This direction would be worth exploring, particulary, in order to understand in what way the indicators and models and the eco-innovation processes are related to each other. The appropriate method for this is an in-depth examination of the scientific literature.

As a new topic, it is worth investigating what indicators related to the EU taxonomy regulation, green investments, ESG regulation, and to observe if they are able to give foresights, and whether they can be formed into a national aggregates.

It is recommended to review the existing metrics for eco-innovation and the green economy that could promote all three strategies for coping with the future changes: future-proof, future-oriented or adaptive strategies. Other measurement systems (EU eco-innovation index, OECD Green Growth indicators), life cycle analysis (LCA), and environmental accounts describing the relationship between the economy and the environment may also be priority areas, and intensity indicators can also be particularly useful for measuring the use of natural resources, and could be investigated, to what extent they describe innovation processes.

During the in-depth analysis of the literature, after defining the environmental criteria, it can be examined whether a system for measuring ecological future readiness can be formed from the existing indicators. For this, it is necessary to explore the processes of the transition to the green economy, the circular economy that appears as a new paradigm, and at the same time to address the related social indicators describing the consumption side and the human resource side in addition to the production orientation of eco-innovation.

Further suggested areas for research are synergies and trade-offs within monitoring systems. During the examination of the SDGs, significant internal forces of this kind were highlighted (Pradhan 2017, Gasper et al., 2019). While economic and social indicators tend to move together due to the welfare-enhancing effect of economic growth, environmental indicators react in the opposite way to the extensive growth of the economy and some social indicators.

Any direction the research continues, the monitoring systems and indicators should also be assessed based on the indicator criteria described by the FPO (transparent, consistent, comparable data, capable of showing changes over time, instead of input, the effect is measured in relation to the good life, reliable, the phenomenon is well understood descriptive indicators suitable for strategic policy planning).

The measurement of environmental sustainability and innovation and resilience will certainly raise difficulties, since the two are built from different sources, so diverse breakdowns will cause discrepancies. While environmental indicators tend to be sourced from land, water monitoring systems and remote sensing, economic and social indicators of innovation and resilience can be compiled from statistical data collections. For this reason, it is necessary to find the common denominator, which can arise mainly at the macro level.

The most interesting direction is the examination of the extent to which the PSR model, which presents a process approach and is widely used in the case of environmental indicators, could be adapted to evaluate the future readiness of monitoring systems in general.

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