sustainability

MDPI

Article

International Collaboration in the Field of Environmental Protection: Trend Analysis and COVID-19 Implications

Yelizaveta Chernysh [1,*] and Hynek Roubík [2,*]

[1] Department of Ecology and Environmental Protection Technologies, Sumy State University, 40007 Sumy, Ukraine

[2] Department of Sustainable Technologies, Faculty of Tropical AgriSciences, Czech University of Life Sciences, 16500 Prague, Czech Republic

* Correspondence: e.chernish@ssu.edu.ua (Y.C.); roubik@ftz.czu.cz (H.R.); Tel.: +380-542-331-205 (Y.C.); +420-22438-2487 (H.R.)

Received: 15 November 2020; Accepted: 9 December 2020; Published: 11 December 2020

Abstract: This paper focuses on the analysis of current cooperation trends in environmental protection research. A unified system of interrelations between research methods in the field of implementation of the bibliometric approach to the review of international cooperation in the field of environmental protection taking into account the consequences of the COVID-2019 pandemic was formed. To form a unified visualization of the analyzed bibliometric data, a special software product VOSViewer was used. Five clusters were defined: green—international cooperation for assessing risks to public health, in particular in the field of biosafety and the spread of social infections, with a focus on COVID-19, in 2019 and 2020; yellow—describes the related interaction between other clusters in the field of national and international mechanisms of cooperation in the regulation of greenhouse gas emissions and climate change; blue—brings together research areas in the field of economics of environmental management and control. The situation concerning the impact of the COVID-2019 pandemic is ambiguous, and it is crucial to recognize that this is a long-term period of impact, not only directly on public health but also due to economic and social constraints, as quarantine activities cause a chain of socio-economic crises. The problems of the environmental and economic spread of COVID-19 on various human activities and the environment require the development of this topic and the formation of a new cluster of interactions due to the wave dynamics of disease in the future. Broad cooperation and collaboration is proposed to address the challenges and accelerate sustainable development in Europe. A diagram of the main cooperation programs has been created, illustrating the overlap of the entire field, from basic research to the market. Further analytical studies will examine the effectiveness of cross-analysis using various scientometric databases to form an integrated approach to the new realities of quarantine activities.

Keywords: environmental protection; international cooperation; COVID-19; bibliometric analysis; visualization software; clusters

1. Introduction

The international importance of global issues requires finding concrete measures to maintain the stability of ecological systems. Cross-border transport leads to the spread of pollution from one state to the territory of a neighboring state. The homogeneity of the biosphere processes and the conditionality of the municipal borders lead to the fact that no exemplary power in terms of careful treatment of nature, with the most effective environmental legislation and law-abiding inhabitants, can be protected from the deterioration of the properties of water, air, land, animal and plant life. Therefore, it is not

enough to improve the legislation and system of nature management exclusively in one's own country; it is also necessary to promote international cooperation and international legislation governing the common efforts of all countries in the field of nature protection [1].

The protection of the environment from harmful impacts implies two main directions [2]:

(i) control (monitoring);
(ii) management (economic measures of environmental regulation).

The implementation of these activities on a planetary scale will not be possible without the close cooperation of as many states as possible in the field of environmental protection.

Thus, there are several challenges and obstacles to sustainable development. These and other issues were on the agenda of the Rio+20 international conference (The United Nations Conference on Sustainable Development (UNCSD)), the main topics of which were [2]:

(i) building a green economy to achieve sustainable development and overcome poverty; helping developing countries to shift to a green development path;
(ii) improving the coordination of international efforts to achieve sustainable development goals.

Effective international cooperation in the field of environmental protection will not be possible without the active participation of international organizations. Such participation is necessary because of certain features of environmental issues.

Firstly, modern science is not yet able to answer questions related to the mechanism of human impact on nature and how it addresses emerging issues. Extensive and costly research is required, the success of which depends in no small part on the existence of permanent global and regional systems for the exchange of scientific information and environmental monitoring [3].

Secondly, given that international agreements are now one of the main forms of the response of the international community to environmental issues, the usual slowness of states in their development, conclusion, and ratification cannot be overlooked. It is thought that traditional diplomacy has largely exhausted itself concerning environmental issues and should be replaced by new normative mechanisms capable of responding adequately to the rapid changes in the state of the environment and the level of scientific knowledge about nature. It is also important to note that the implementation of the international legal obligations already undertaken by states remains highly relevant. To increase the effectiveness of environmental conventions, it is necessary, on the one hand, that the obligations of the parties be more specific and, on the other hand, that there be bodies to monitor their implementation, such as those established under international agreements [4].

Thirdly, environmental problems are characterized by their close, objectively related relationship to economic development, population control, and poverty reduction. This means that the adoption of measures aimed at overcoming negative environmental trends must take into account social, demographic, and economic factors.

Fourthly, it is important to assess the impact of the pandemic dynamics of COVID-2019 on the processes of international cooperation in the field of environmental security, as it is a new challenge that has affected the world economy and the social priorities of entire states.

We decided to take bibliometric analysis as the main approach to studying the analysis of current trends in environmental research cooperation. It should be noted that an effective tool for the implementation of bibliometric analysis of the scientometric space are programs for visualization of trends in the development of scientific knowledge. Thus, in the work of Yi-Ming Guo et al. (2019) bibliometric analysis was applied using the VOSViewer visualization software to review the area related to "smart cities" from the point of view of regular publications, the main field of activity of "smart cities" researchers, and consider possible directions of development of this subject [5]. Wenjie Zhang and Hongping Yuan (2018) analyzed the topic of research in the field of energy performance contracting and formed mechanisms to implement project cooperation in this area, defining a network of relationships with the use of bibliometric analysis and the VOSViewer software [6]. The research methodology of

Josué Briones-Bitar et al. (2020) consisted of the following stages: data compilation, software and data cleaning, and analysis, interpretation, and visualization. Moreover, it allowed the authors to assess disaster risks and to analyze the limitations of current research to shape the future direction of new research [7]. Dorin Maier et al. (2020) provided a bibliometric approach using visualization software to review the development of sustainable innovation from the perspective of a more practical approach with a commercialization component for new technologies, products or services, and entrepreneurship. As a result, a basis was created for the subsequent synthesis of research results in the field of sustainable innovation [8].

As can be seen, bibliometric analysis of research trends is very widely used in various areas of scientific knowledge, in particular, sustainable social development and the introduction of new areas of cooperation for innovation development. Therefore, we believe that the bibliometric approach can be effectively applied to the analysis of international cooperation in the field of environmental protection. At the same time, it is necessary to note the importance of the issue of COVID-2019 influence in this area. We have limited the scope of analysis of the bibliometric approach in the context of the research subject. Of course, COVID-2019 has an extensive sphere of influence, that can be studied in different areas of economic and social development, health care, and industrial potential. In this article, we intend to delve deeper into the analysis of a specific research area related to international cooperation projects in environmental issues that are affected by the COVID-2019 situation.

Therefore, this paper focuses on the analysis of current trends in cooperation in environmental protection research. To achieve this aim, the following tasks were set: (i) analysis of the dynamics of cooperation in the field of environmental research; (ii) visualization of the relationship in international cooperation under environmental protection research taking into account the impact and the implications of the COVID-19.

2. Materials and Methods

2.1. Methodological Approach

The bibliometric approach is a reliable methodological basis for analyzing trends in scientific research in various fields. Bibliometric analysis was used to analyze the research results and publication trends in the scientific field of international cooperation and environmental protection. It should be noted that scientometry is a form of quantitative analysis based on specialized data sources. Quantitative analysis is possible only if there are data sources relevant to the tasks being solved [9]. This can be done by analyzing the English-speaking segment of such global political information and analytical resources as Web of Science (WoS) and Scopus, produced by Clarivate Analytics and Elsevier, respectively. Research papers (including original papers and conference proceedings) are the main type of publication, and English is the most widely used language, which is why this language segment was chosen. The data obtained show the dynamics of changes in the number of publications and relevant citations [10].

In this analysis, Scopus databases were used. Its resources make it possible to conveniently and quickly track the citations of studies published in scientific journals. Both databases allow search and sorting of results by expected parameters such as first author, citation, institution, the impact factor, the h index, etc. [11]. It is worth mentioning the high correlation between these databases, which has been studied in several works [11,12]. Of course, it is necessary to compare them when in search of certain research areas. The Scopus database indexes journals, conference proceedings, and books, but unlike WoS, it is not divided into separate databases, and Scopus covers more journals than WoS [13].

To carry out the search in each database system, keywords under different topics were used, in the following combinations: environment, international cooperation, environmental protection and COVID.

The correct use of citation indexes and bibliometrics is essential for the following tasks [13]:

1. Find adequate information on the subject under study with the possibility of detailed analysis by authors, organizations, countries, etc.
2. Analyze actual research directions and interrelations between different directions.
3. Obtain supporting objective data for the evaluation of research results.

We used the bibliometric analysis as the main approach for studying the area of international cooperation on environmental issues and the impact on this process. We can highlight the following advantages of this method; it allows us to: integrate information about the subject area in a single information resource; obtain the necessary amount of data on a particular subject-oriented topic, ensure the adequate display of the state of the subject area of research; and provide an opportunity for analysis using information technologies.

Bibliometric analysis of scientometric databases allows us—regardless of our own ideas about the importance of the problem and the degree of its coverage in the media—to obtain real data on the number of scientific publications on a particular issue, the sources of this information and the publications that most fully cover it, the authors (their publication activity), the assessment of the articles by the scientific community (on bibliometrics), and eventually, based on all of the above factors, to form a professional opinion on the environmental issues and international cooperation in this field that are most significant and highlighted by scientists, as well as the impact of the current situation with COVID-2019. The array of publications for bibliometric analysis in the field of international cooperation and environmental protection in databases such as Scopus and Web of Science was identified on the basis of specialized queries on a set of keywords related to the areas under consideration in the field of environmental studies, verified by experts, with special attention to the impact of COVID. Further, an empirical research database (Figure 1) was formed based on the sets of keywords specified for this area.

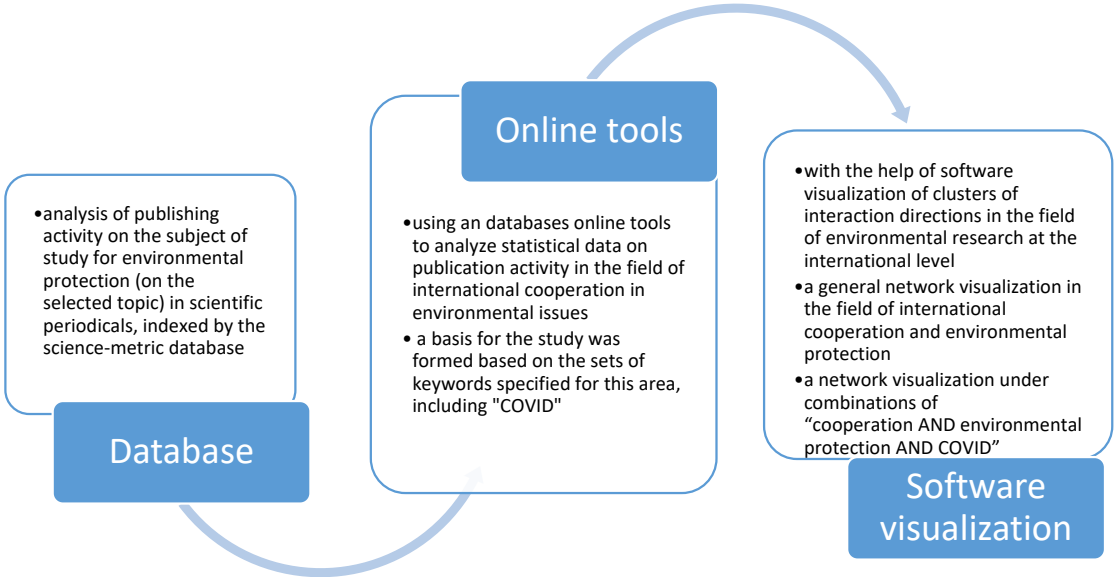

Figure 1. System of interrelation of research methods in the sphere of implementation of bibliometric approach to the review of international cooperation in the environmental protection field taking into account the impact of the COVID-2019 pandemic.

As can be seen from Figure 1, an important element is the formation of a unified system of visualization of analyzed bibliometric data, for which a special software product, VOSViewer, was used.

2.2. Visualization Software

VOSviewer is an open access program that can be used for various purposes. VOSviewer can be used to create maps based on a data network. Maps are created using VOS mapping technology and VOS cluster highlighting technology. VOSviewer can be used for viewing and investigating maps. The program displays the map in various ways, each of which highlights its different aspects. It offers features such as zoom, scroll, and search, that make it easy to thoroughly explore the map. VOSviewer was originally conceived to analyze bibliometric networks. The program can be used, for example, to create maps of publications, articles, or journals based on a social network or to create keyword maps based on their simultaneous appearance on the network [14].

VOSviewer, developed by the Centre for Science and Technology Studies of the University of Leiden (https://www.cwts.nl), was used to analyze and visualize the data obtained. The program allows users to work with data from different sources (WoS, Scopus, Dimensions, CrossRef, Medline), and it is regularly updated, distributed free of charge, and does not require installation.

The work with this program was carried out using the following protocol:

Step 1: Run the file VOSviewer.exe

Step 2. Choose to Create a map based on bibliographic data

Step 3: On the Scopus tab, specify the location of the CSV file.

Step 4: Choose, in the corresponding sections, Co-occurrence, All keywords, Full counting.

Step 5: The program analyzes the file and offers to enter the threshold of keywords to remove very rare terms from the analysis.

Step 6: The program will offer to reduce the number of terms for which the calculation will be performed to 1000. We refused this automatic setting and chose the full number (2441).

Step 7: VOSviewer offers a last look at the list of terms, with the possibility to edit it manually. This is an important step, as it allows for the removal of terms which are too generic—such as human, humans, article, male, female, etc. By removing uninformative terms, we increase the specificity of links between publications, which should have a positive effect on the clustering result.

By default, the program identifies several large zones (clusters) in which different areas of research are formed. In this case, as described in the report of van Eck and Waltman (2009) [15], the density of the elements of a point on the map depends on both the number of neighboring elements and the weight of these elements. The larger the number of adjacent elements and the smaller the distance between these elements and the point of interest, the higher the density of the elements. Besides, the greater the weight of neighboring elements, the higher the element density [15].

Thus, VOSviewer is a service for fast data processing from scientific citation indices and reference databases, and for the reflection of existing links in the format used for the analysis of network structures.

3. Results and Discussion

3.1. Dynamics of Cooperation in the Field of Environmental Research

Figure 2 shows the changes in the number of publications by year in the journals that are indexed in the Scopus database. If we look at the distribution of the share of publications by topics of environmental cooperation (Figure 2) since 1974, there has been an increase in publication activity in this area. Over the past decades, there has been a clear trend toward addressing many environmental security issues at the inter-state level. The impetus for international cooperation on environmental issues at the level of states was provided by the Stockholm Conference (1972) [16], and can also be attributed to the increased interest in this topic in publications since the 80s of the last century.

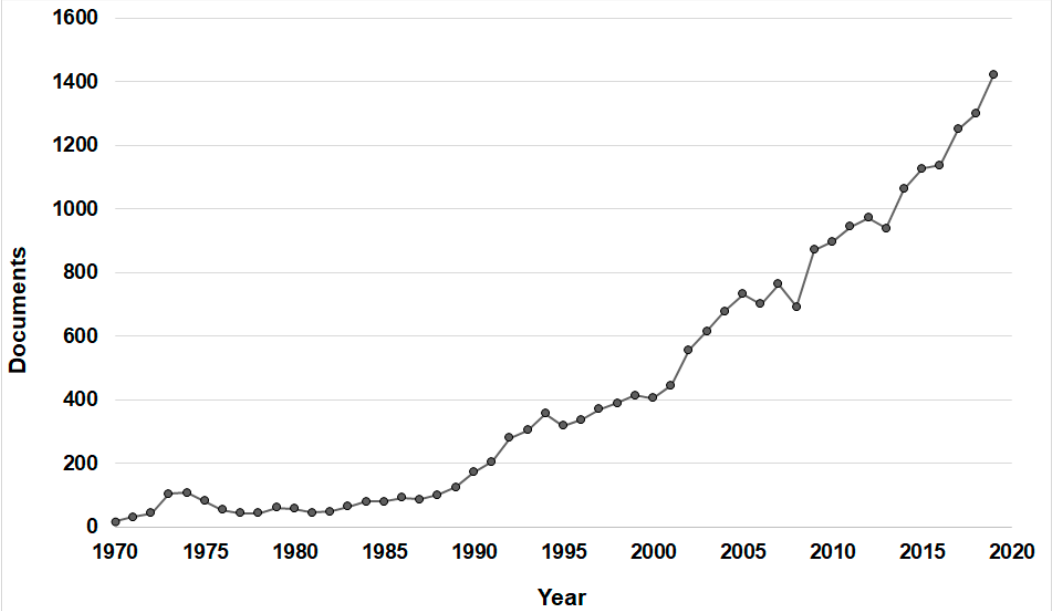

Figure 2. Publication activity curve over the years based on Scopus database data by topics of environmental cooperation (1974–2019).

In 1982, the United Nations adopted the "World Charter for Nature", which proclaimed for the first time at the international level the responsibility of mankind for the state of nature. The Rio de Janeiro Conference adopted a policy document, Agenda 21 (1992), replacing the international environmental action plan at the transition from the twentieth to the twenty-first century. Its implementation over the decade was summed up at the World Forum in Johannesburg in 2002 as disappointing [17]. The "Humanity and Global Change" program is being implemented to explore the interrelationships in the "Human Environment for Life" system [18].

When analyzing the curve of publication activity (Figure 2), we can note the choice of the period of data aggregation since 1990, where the trend of strengthening and developing the concept of sustainable development in the world is determined. The Fifth Programme of Action for the Environment of the Community, adopted in 1993 and entitled "Towards sustainability", was fundamental in its content. The Fifth Programme of Action for the Environment adopted the EC concept of sustainable development, which became the official UN strategy for mankind's recovery from the environmental crisis after the 1992 UN Conference on Environment and Development in Rio de Janeiro (Rio 92) [19].

The new program of environmental actions, as a whole, aims to provide three conditions for environmental actions in the Community [20]:

(i) Integration of the needs of the environment into the various activities of the EU and implementation of the principle of environmental conditionality of Community activities as set out in Article 6 of the Treaty establishing the EU;
(ii) Continuation of activities aimed at ensuring sustainable development;
(iii) Conducting environmental activities with a view to the current and future enlargement of the European Union, i.e., accession of new states to it.

The Programme also defines the main tasks of the organization in the field of international cooperation on environmental issues and establishes the criteria for the formulation of environmental policy based on the processing of relevant information and the acquisition of new data [4].

Figure 3 shows the subject area of research on different sources of publications, which shows its connection with different scientific directions. Publications in the natural sciences, social sciences, and medicine are dominant. There is also interaction at the interface of sciences with a trend toward

engineering implementation of environmental solutions, development of green agriculture and energy, and economic substantiation of environmental processes in transboundary cooperation.

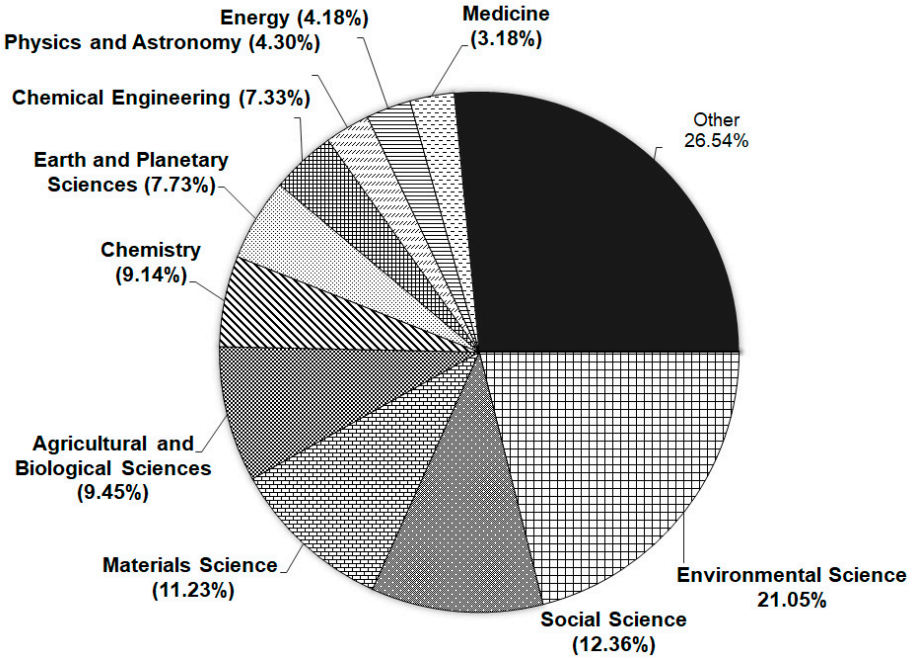

Figure 3. The subject area of publications in the field of international cooperation and environmental protection on Scopus database data.

As can be seen in Figure 4, the main sources of research funding can be attributed to the National Natural Science Foundation of China (485 publications), the European Commission (210), the National Science Foundation (193), the National Institutes of Health (146), and the U.S. Environmental Protection Agency (74).

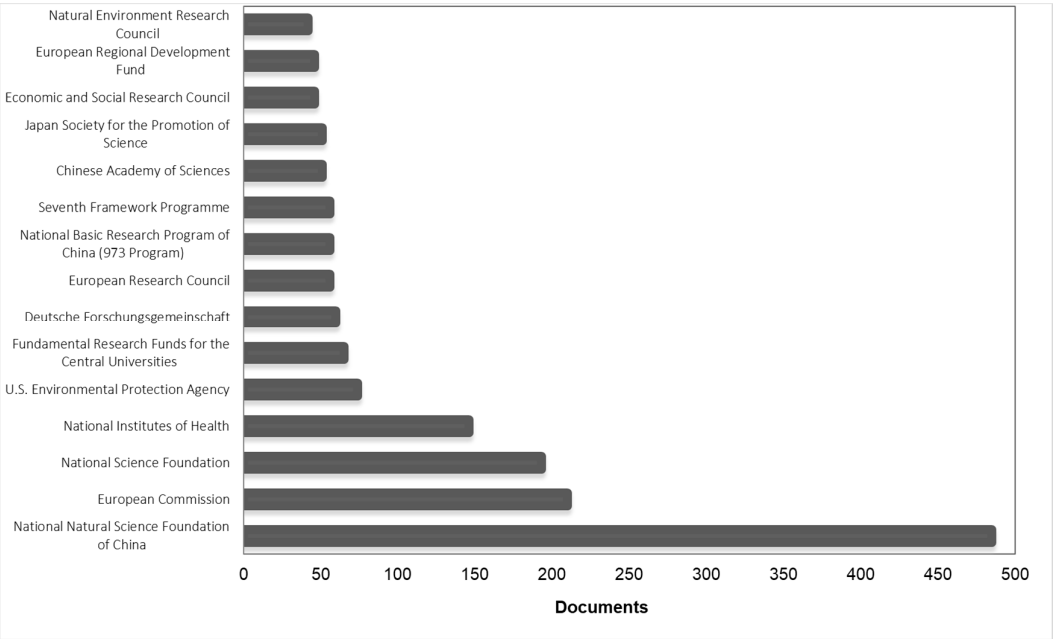

Figure 4. Sources of funding for publications in the field of international cooperation and environmental protection on Scopus database data.

China is actively involved in international cooperation in the field of environmental protection [21,22], and the National Natural Science Foundation of China supports a financially significant number of environmental and conservation projects (Figure 4), which affects the publication activity of Chinese scientists (Figure 5). Today, the European Community (EC) is one of the leaders in environmental cooperation in the European continent, while the environmental policy and activities of the Community are inextricably linked with global activities, in particular those conducted under the auspices of the UN, in the field of environmental protection [23]. Based on the provisions of the founding treaty, EC practice in the field of ecology is based on a special medium-term environmental action program. The Environmental Action Programme sets out specific goals and objectives which the Community can achieve and implement in the light of the current situation [24]. In general, the United States Environmental Protection Agency, as the National Science Foundation and the National Institutes of Health, supports different areas of cooperation in the field of environmental protection [25]. Accordingly, as can be seen in Figure 4, publication activity in the United States on international cooperation and environmental protection is the highest compared to other countries.

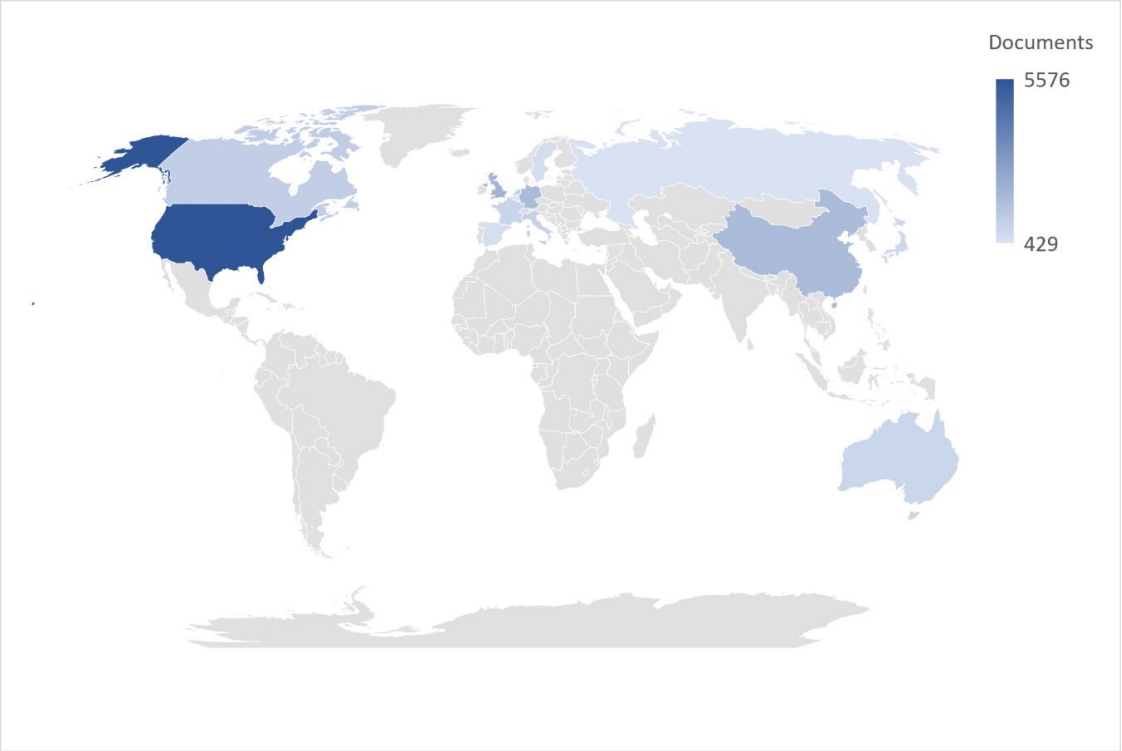

Figure 5. Distribution of countries with the highest rates of publication activity in the field of international cooperation and environmental protection according to data from the Scopus database.

Climate change and environmental degradation are an existential threat to Europe and the world. Accordingly, the European Green Deals aims to limit greenhouse gas emissions by 2050 and promote the comprehensive development of resource-efficient technologies [26].

The General Secretariat of the Commission assesses whether new policy initiatives can afford to postpone their implementation because they are not directly related to COVID-19 or are considered less important for the achievement of absolute key priorities (Table 1). On 7 April 2020, the priority actions of the first ERAvsCorona Action Plan were approved as a result of dialogues between the Commission's services and national ministries [27]. It is important to create a single platform for the exchange of SARS-CoV-2 research data and COVID-19-related information, i.e., a single scientific ecosystem that will enable the rapid exchange of data and research results in an open collaborative format in real-time.

Table 1. Green policy initiatives and the impact of COVID-19. Based on data from [28].

Maintained Initiatives	Initiatives Delayed Until 2021
Updated Sustainable Financing Strategy. This is considered an important part of the Green Deal and a "key factor" in the recovery from the COVID-19 crisis and will, therefore, be preserved.	The new EU climate change adaptation strategy and the new EU forest strategy.
A wave of renewal as a key element in any post-COVID recovery plan because of its benefits to stimulate economic activity.	Consumer empowerment for "green" transition. This initiative is an important element of the "Circular Economy" package, whose technical work is on schedule. However, this consumer empowerment initiative can be postponed until 2021 and can be complemented by circular economic initiatives on sustainable products.
Climate Target 2030 is a "key element of the Commission's climate policy". However, with the move of the UN climate conference to Glasgow (COP 26), additional time could be allocated to the complex analytical work of developing new targets.	ReFuelEU aviation fuel is sustainable aviation fuel and FuelEU marine green European maritime space.

For a subregion that is home to 36 percent of the world's poor, the Agenda 2030 provides South Asia with an opportunity to reduce poverty and improve the quality of life. The study of Kumar (2019) shows that there is great potential for regional cooperation and coordination in the implementation and monitoring of the Agenda 2030 among countries in South Asia to build productive capacities through a coordinated industrial development strategy, harness the potential of regional value chains by strengthening transport links and simplifying procedures, enhancing their collective energy and food security, and building resilience to natural disasters [29]. However, the development of an environmental safety net should be an integral basis for regional cooperation.

The current level of transboundary pollution of the natural environment and the global nature of environmental problems, which require adequate preventive measures at the inter-state level, result in the emergence of new non-traditional problems in international relations, such as [2]:

- development and operation of a global monitoring system for the natural environment and its components.
- creating conditions for quality management in the field of environmental protection.
- development of international environmental management standards.
- establishment of an international environmental safety system.
- introduction in the practice of international relations of effective mechanisms of economic and legal responsibility for environmental violations, which may cause degradation of environmental components and subsequently lead to the loss of ecological balance.
- public access to reliable environmental information.
- coordination of international efforts with a view to transition to the model of sustainable development of human civilization.

Environmental monitoring and assessment include [30]:

(i) assessment of the current quality of the environment in terms of environmental integrity, i.e., paying attention to the function and stability in the region.
(ii) assessment of the state of natural resources, development trend.
(iii) monitoring the history, status, and development of the major ecosystem and environmental problems, such as the destruction of vegetation, desertification, endangered animals and plants, natural disasters, declining land productivity.

The structure of the Pressure-State-Response (PSR) created in this document relates mainly to the following indicator from remote sensing, which has not considered social and economic statistics for the PRS model implementation, and retains therefore some uncertainty about the interference of society. Meanwhile, the remote sensing of data speaks to the strategy's shortcomings and fragility. Due to the population growth and economic development have, biodiversity conservation is facing an increasing number of challenges [30,31]. The efficiency of restoring the ecological integrity of nature reserves has become a critical issue of concern to society. For example, the work of Wu et al. (2016) examined the existing nature parks and reserves that have been restored and conserved in large numbers in the Mekong Subregion by ensuring the conservation of biodiversity through a corridor connecting the divided habitat of wild animals [31].

A study by Bacon et al. (2020) identified the importance of the necessary conditions for both cooperation and non-competitive partnership. Through a vaguely defined qualitative comparative analysis (fsQCA) and configuration recipes for conditions, various configurations were identified as necessary for both collaboration and non-competitive activities of the partnership in the context of innovative ecosystems. However, there is no unified approach uniting all the trends of interaction between partners in a consortium for the implementation of sustainable development goals of a transboundary nature in environmental research [32].

The study by Bulmash (2019) demonstrates the impact of environmental values on employee attitudes toward business owners and managers. It describes the impact of changing social values on business and standards, with a focus on the increasing role of environmental movements around the world [33].

The main cooperation programs can be presented in a diagram (Figure 6) that illustrates the overlap of the entire field, from basic research to the market. A study by Planko et al. (2019) examines strategies for cooperation for sustainable development at the network level. Companies implementing innovative technologies and supporting sustainable development should collaborate with other actors in the innovation ecosystem, including their competitors, so that they can develop standards, interoperable products, pool knowledge as well as resources and join forces to compete with other technologies [34]. A study by Rahmani et al. (2020) analyzed the different types of cooperation between supply chain actors as an option to manage each of the channels more efficiently. This can be used at the level of interaction with contractors performing certain jobs of an international consortium partner (subcontracting) [35].

Thus, the main forms of international cooperation in the field of environmental protection, rational use of natural resources, and environmental security include [2]:

- Parliamentary cooperation between states to address global and regional environmental issues, the joint use of universal, multinational, and transboundary natural sites, and cooperation between Governments for the implementation of international environmental programs and projects;
- Cooperation between individual countries and international environmental organizations to coordinate joint environmental activities;
- International legal cooperation between countries to develop common approaches to solving environmental problems and rational use of natural resources, as well as to prevent and eliminate the negative consequences of the anthropogenic impact on the environment;
- Creation of special international environmental organizations;
- Organization and holding of international conferences and forums on environmental protection issues;
- Exchange of experience, technologies, knowledge, and information in the field of environmental protection and rational use of natural resources;
- Involving the public, public organizations, and business structures in international environmental cooperation.

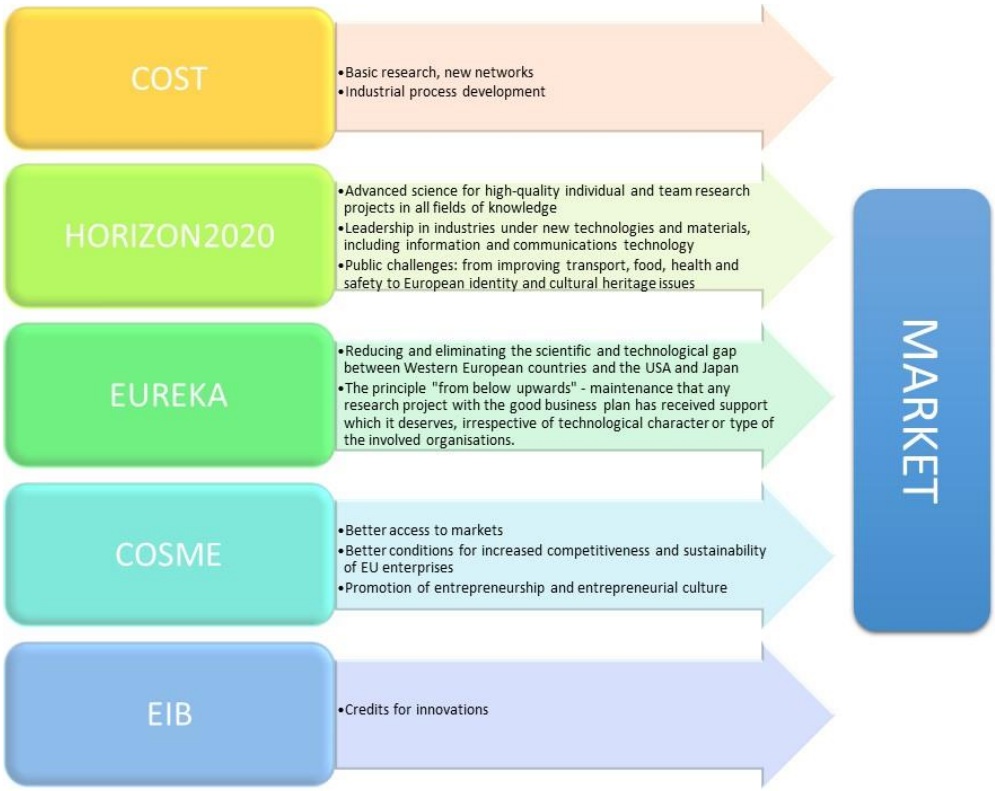

Figure 6. Programs to promote international cooperation, particularly applicable to the field of environmental protection.

The Case of Ukraine in the Direction to the European Research Area

One of the vectors of expansion of the Ukrainian research space is the direction to the European Research Area (European Research Area–ERA, http://ec.europa.eu/research/era/eraprogress_en.htm). An ERA is a wide range of connections and communications, which are beyond the geographical boundaries of Europe. It can be characterized by the following main characteristics: integration, strengthening, structuring, stimulation of investments in R&D, education, employment, expansion. These features form the main priorities of the ERA: more efficient national scientific systems; optimal transnational cooperation and competition; open labor market for scientists; gender equality; optimal exchange of scientific knowledge [36]. The ERA meets many current global challenges, for example, the creation of a single digital market in Europe (https://ec.europa.eu/digital-single-market/en/europe-2020-strategy). It is to meet the challenges and accelerate sustainable development in Europe that broad cooperation and collaboration is proposed. The main cooperation programs at the ERA can be presented in a diagram that illustrates the overlap between the whole field, from basic research to the market. In 2015, Ukraine became an associate member of the European Union's Framework Programme for Research and Innovation "Horizon 2020" (https://www.kmu.gov.ua/en/yevropejska-integraciya/ugoda-pro-asociacyu). This membership gave Ukrainian participants equal status vis-à-vis their European partners and opened up opportunities to influence the content of the program.

3.2. Visualization of the Relationship in International Cooperation under Environmental Research

Figure 7 shows the visualization of interaction zones by keywords in publications on the theme of international cooperation in environmental research and conservation. Five clusters were identified (Figure 7): green—international cooperation for assessing risks to public health, in particular in the field of biosafety and the spread of social infections, with a focus on COVID-19 in 2019 and 2020; yellow—describes the related interaction between other clusters in the field of national and

international mechanisms of cooperation in the regulation of greenhouse gas emissions and climate change; blue—brings together research areas in the field of economics of environmental management and control.

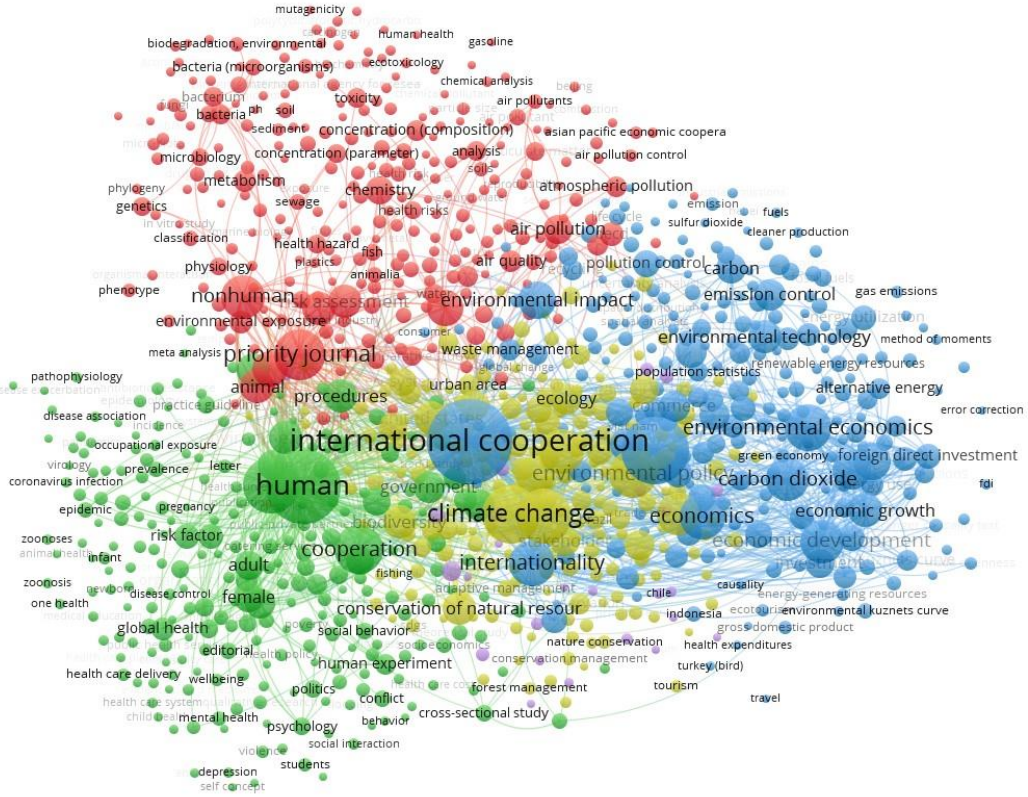

Figure 7. General network visualization in the field of international cooperation and environmental protection (constructed via VOSViewer v.1.6.15): 5 clusters, 69,682 links, 131,761 total link strength (green—international cooperation for assessing risks to public health, in particular in the field of biosafety and the spread of social infections, with a focus on COVID-19 in 2019 and 2020; yellow—describes the related interaction between other clusters in the field of national and international mechanisms of cooperation in the regulation of greenhouse gas emissions and climate change; blue—brings together research areas in the field of economics of environmental management and control).

Central to the development of international cooperation in environmental protection is climate change on the planet (Figure 7). Global temperatures can rise continuously in most parts of the world, and changes in precipitation, extreme events, and sea-level rise will vary from place to place and from year to year, similarly creating local, regional, and public emergencies that require a thoughtful approach and international cooperation to manage them [37].

As stated in a study by Gaura et al. (2020), the creation of waste-free recycling facilities is quite difficult, so strategies need to be adopted to reduce waste generation or convert it into high-quality products. Under this approach, a number of national and international public authorities have developed policies governing the purchase of raw materials, the production of goods, and the disposal of waste. These policies focus more on the reuse and recycling of waste but give priority to waste prevention. In this regard, the valorization of such industrial waste, which contains large quantities of macromolecules and biologically active compounds, is an effective strategy to contribute to the reduction of hazardous waste while ensuring the economic efficiency of the process through the production of value-added products of industrial and social importance [38].

At the same time, cooperation in the commonwealth of industrial sector partners with scientific organizations, within the framework of international programs, becomes more and more important for the realization of innovative approaches in the sphere of environmental protection and climate change.

Results obtained by Liu et al. (2020) showed that developing countries share "common but differentiated responsibilities" with developed countries, as emphasized in the Kyoto Protocol and the Paris Agreement. Thus, at an early stage of economic growth and capital accumulation in developing countries, developed countries need increased environmental investment to assist developing countries. As developing countries continue to improve their economies, they can afford to invest in pollution control, which will reduce the necessary environmental investments from developed countries. Moreover, in this way, developing and developed countries can control pollution without significant social losses to their well-being [39]. This study, conducted by Chinese scientists, characterizes China's development dynamics as having a significant economic potential, and that the development agenda also includes environmental priorities. It should be noted that developing countries have very different dynamics of economic potential, and with the quarantine activities caused by the COVID-19 pandemic, funding for environmental research has declined significantly, as has a green investment.

For a more detailed consideration of the impact of COVID-19 on the trends of international cooperation in the field of environmental research, the term "COVID" was added during the search in the database, and a network of visualization of keyword interaction in publications was formed, which is presented in Figure 8. Two clusters are highlighted here: a red cluster associated with research on coronavirus infections and their pandemic spread, and international collaboration to counteract this spread; a green cluster describes the current state of COVID-19 and increasing publication activity in this research area. It should be noted that this direction considers the impact on human health and refers more to the medical sciences.

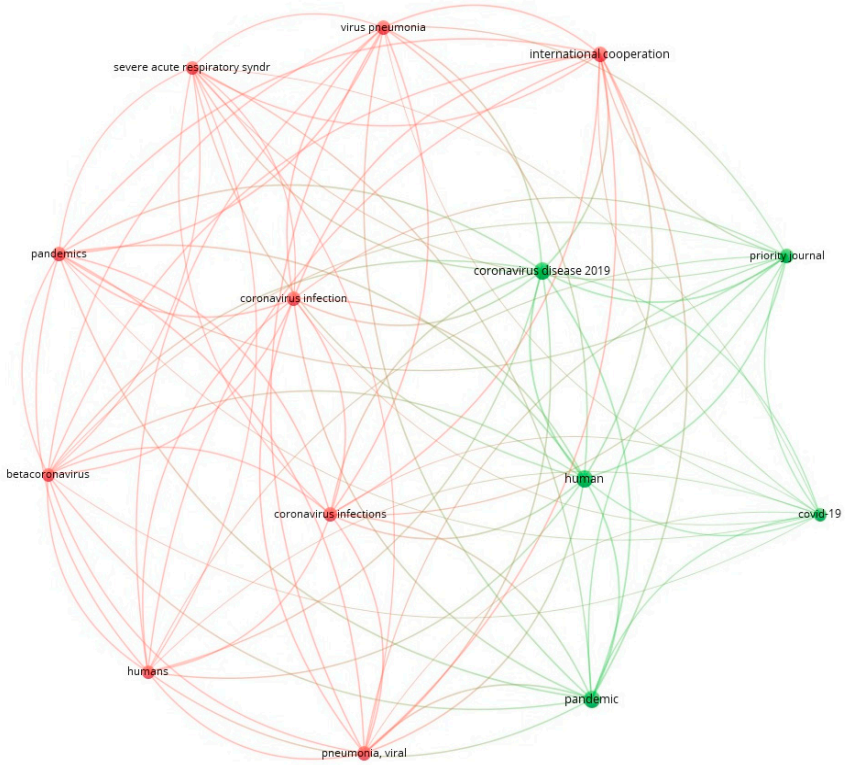

Figure 8. The network visualization under the combinations of "cooperation AND environmental protection AND COVID" constructed via VOSViewer v.1.6.15): 2 clusters, 91 links, 452 total link strength (the red cluster showing research on coronavirus infections and their pandemic spread, and international collaboration to counteract this spread; the green cluster describes the current state of COVID-19 and increasing publication activity in this research area).

At the same time, we analyzed current research in this area, in the context of the environmental, and economic spread of COVID-19 and its impact on various human activities and the environment will require the development of this topic and the formation of a new cluster of interactions in publishing activities due to the wave dynamics of diseases in the future. As has been studied in many papers [40–42], quarantine activities in themselves have had some positive impact on the environment. Recent data republished by NASA (National Aeronautics and Space Administration) and ESA (European Space Agency) show that the pollution of some epicenters of COVID-19, such as China, Italy, Spain, the United States, etc., has decreased to 30 percent [40]. This is due to the effect of quarantine measures introduced as a consequence of the spread of the COVID-19 pandemic and is an example of its environmental and economic impact on social development. If COVID-19 had not spread and restrictions had not been imposed on industrial facilities, there would have been no reduction in environmental pollution. Therefore, these pollution reduction effects are directly related to the reduction of pollution activities due to the introduction of quarantine measures to prevent the spread of COVID-19.

As set out in the work of Manzanedo and Manning (2020) [37], the following changes in collaboration may be useful in the future:

(i) To prevent climate change, it can be reported as an investment without the necessary returns, just as most of us take out personal health insurance, where we accept the cost of protecting ourselves from potential negative impacts that may never occur. Such actions should prevent public resistance to costly climate change-related actions and the risk of inaction.

(ii) Data on the COVID-19 pandemic to date show that countries that have reported consistently and seriously to the public about the consequences and risks of the pandemic (e.g., Germany, New Zealand, South Korea) have been more effective in containing the disease than countries that have denied or understated the risks and have reported inconsistently to the public (Manzanedo and Manning, 2020) [37].

However, the situation with the impact of the COVID-19 pandemic is ambiguous, and it is crucial to recognize that this is a long-term period of impact, not only on public health directly, but also through economic and social constraints, and quarantine activities trigger a chain of socio-economic crises, as seen in Ukraine. At the same time, funding for health and environmental protection programs is significantly insufficient.

As stated in the study by Manzanedo and Manning (2020) [37], climate change governance faces the same challenge as combating the COVID-19 epidemic—to report on the need for timely and decisive action in the face of a distant threat aggravated by the global nature of the problem and the lack of counter-examples between countries to demonstrate success. The work done during the COVID-19 crisis to maintain public confidence in scientists and to build public understanding of risk aversion can help lay the foundation for efforts to build social momentum for preventive action to protect against climate change. Such initiatives are needed to encourage policymakers to prioritize long-term security over short-term costs and economic benefits [37]. The European Commission has developed and approved a plan for Horizon Europe, which aims to increase EU funding for science by 50% over the period 2021–2027, to overcome the crisis caused by the spread of COVID-19 [43]. To address the long-term impact of COVID-19, the UNDP Regional Bureau for Europe and Central Asia is launching BOOST, a regional program to accelerate social innovation. It will support new solutions in the digital, economic and health fields [44].

4. Conclusions

This paper presents an analysis of the dynamics of international cooperation in the field of environmental research, including a thematic area of research on different sources of publications, which shows its connection with different scientific directions. Publications in the natural sciences, social sciences, and medicine predominate. At the interface of sciences, there is also interaction with the

trend of engineering implementation of environmental solutions, development of "green" agriculture and energy, and economic justification of environmental processes in transboundary cooperation. The historical dynamics of formation of publishing activities in the field of international cooperation on environmental problems, in particular climate change, is analyzed, and the main international milestones of such cooperation and their impact on research in the field of environmental protection are outlined.

With the help of VOSviewer, several large zones (clusters) have been identified in which different areas of environmental research are being formed, taking into account the impact of COVID-19. At the same time, as the zonal distribution in the process of visualizing the main clusters has shown, it is the theme of climate change that is of primary importance in international cooperation, taking into account the distribution trends of COVID-19. The situation concerning the impact of the COVID-2019 pandemic is ambiguous, and it is crucial to recognize that this is a long-term period of impact, not only directly on public health but also due to economic and social constraints, as quarantine activities cause a chain of socio-economic crises.

Further analytical studies will review the effectiveness of cross-sectional research using different platforms of scientometric databases, in particular WoS, to form an integrated approach to assess environmental trends and prospects for international cooperation in the new realities of quarantine activities.

Author Contributions: Conceptualization, methodology, formal analysis and writing—original draft preparation, Y.C.; Conceptualization, writing—review and editing, funding acquisition, H.R. All authors have read and agreed to the published version of the manuscript.

Funding: The research is carried out as part of a research project of the Department of Ecology and Environmental Protection Technologies, Sumy State University, according to the scientific and technical program of the Ministry of Education and Science of Ukraine (state registration no. 0116U006606) (Y.C.). Furthermore, this research was funded by the Internal Grant Agency of the Faculty of Tropical AgriSciences, Czech University of Life Sciences, Prague, grant no. 20205008 (H.R.).

Acknowledgments: In addition, we are thankful to the Czech Development Cooperation, which enabled this cooperation.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Chizhdenko, A. International cooperation in the field of environmental protection. *Int. Sci. J. Internauka* **2017**, *6*, 83–86.
2. Fedun, O. The ecologization of international relations in context of sustainable development. *Visnyk Lviv. Univ. Ser. Int. Relat.* **2012**, *30*, 78–86. Available online: https://intrel.lnu.edu.ua/wp-content/uploads/2015/09/VLNU_Mv_2012_30_11.pdf (accessed on 11 September 2020).
3. Dubovych, I.A. International cooperation of Ukraine in the field of environmental law, environmental policy and ecological economics. *Sci. Bull. Unfu.* **2006**, *16*, 1316–1320. Available online: https://nv.nltu.edu.ua/Archive/2006/16_1/316_Dubowicz_16_1.pdf (accessed on 1 August 2020).
4. Gerasimov, A.N.; Zyuzin, S.G.; Solovyev, A.I. International collaboration in environment guard and ensuring ecological safety of population spheres. *Naýchnaıa Mysl.* **2019**, *8*, 43–51.
5. Maier, D.; Maier, A.; Aşchilean, I.; Anastasiu, L.; Gavriş, O. The relationship between innovation and sustainability: A bibliometric review of the literature. *Sustainability* **2020**, *12*, 4083. [CrossRef]
6. Briones-Bitar, J.; Carrión-Mero, P.; Montalván-Burbano, N.; Morante-Carballo, F. Rockfall research: A bibliometric analysis and future trends. *Geosciences* **2020**, *10*, 403. [CrossRef]
7. Wenjie, Z.; Hongping, Y. A bibliometric analysis of energy performance contracting research from 2008 to 2018. *Sustainability* **2019**, *11*, 3548. [CrossRef]
8. Guo, Y.i.-M.; Huang, Z.-L.; Guo, J.; Hua, L.; Guo, X.-R.; Nkeli, M.J. Bibliometric analysis on smart cities research. *Sustainability* **2019**, *11*, 3606. [CrossRef]

9. Akoev, M.A.; Markusova, V.A.; Moskaleva, O.V.; Pislyakov, V.V. *Guidance on Sciencecometry: Of Science and Technology Development*; Ekaterinburg Publishing House: Ekaterinburg, Ural, Russia, 2014; 250p. Available online: https://elar.urfu.ru/handle/10995/40130 (accessed on 23 August 2020).
10. Borgoyakova, K.; Bychkova, E.; Zemskov, A.; Kondrasheva, I. Bibliometric analysis of scientific publications in ecology based on the RNPLS&T's reference database "Ecology: Science and technologies". *Sci. Tech. Libr.* **2017**, *10*, 54–68. [CrossRef]
11. Joshi, A. Comparison between scopus & ISI web of science. *J. Glob. Values* **2016**, *7*, 1–11. Available online: http://anubooks.com/wp-content/uploads/2017/08/2016-7-JVG-No.-1-1.pdf (accessed on 11 September 2020).
12. Al Ryalat, S.A.S.; Malkawi, L.W.; Momani, S.M. Comparing bibliometric analysis using pubmed, scopus, and web of science databases. *J. Vis. Exp.* **2019**, 152. [CrossRef]
13. Moskaleva, O.V.; Akoev, M.A. Scientometrics: A little bit of history and modern Russian realities. *Sci. Manag. Theory Pract.* **2019**, *1*. [CrossRef]
14. Mazov, N.A.; Gureyev, V.N. Software for scientometric and bibliometric research: A brief overview and comparative analysis. In Proceedings of the Digital Libraries: Advanced Methods and Technologies: XV All-Russian Scientific Conference "RCDL 2013", Yaroslavl, Russia, 14–17 October 2013; p. 122.
15. Van Eck, N.J.; Waltman, L. Vosviewer: A Computer Program for Bibliometric Mapping. ERIM Report Series Reference No. ERS-2009-005-LIS. 2009. Available online: https://ssrn.com/abstract=1346848 (accessed on 13 October 2020).
16. Homenko, M. Problems of adaptation of Ukrainian ecological legislational law. *Enterp. Econ. Law* **2019**, *10*, 90–94. [CrossRef]
17. United Nations. Agenda 21. 2019. Available online: https://sustainabledevelopment.un.org/outcomedocuments/agenda21 (accessed on 28 August 2020).
18. Ursul, A.D.; Ursul, T.A. Security problem: Global and universally-evolutionary aspects. *Secur. Quest.* **2012**, *1*, 81–159. [CrossRef]
19. Perga, T.Y. *Global Environmental Policy and Ukraine: A Monograph*; Publisher of Emergency Lysenko, N.N: Nizhyn, Ukraine, 2014; 288p. Available online: http://history-pages.kpi.ua/wp-content/uploads/2016/07/42_13_Perga.pdf (accessed on 1 August 2020).
20. European Commission. The Sixth Environment Action Programme of the European Community 2002–2012. 2014. Available online: https://ec.europa.eu/environment/archives/action-programme (accessed on 15 August 2020).
21. Kolpakova, T. Chinese "environmental diplomacy" and the formation of the international system of environmental protection. *Izv. Herzen Russ. State Pedagog. Univ. Ser. Ecol.* **2010**, *70*, 68–74. [CrossRef]
22. Arzieva, D.K. The main directions of China's international cooperation in the field of environmental protection. *Bull. Jusup Balasagyn Kyrg. Natl. Univ.* **2019**, *2*, 105–111. Available online: https://elibrary.ru/item.asp?id=38226096 (accessed on 23 October 2020).
23. European Commission. The EU—Setting the Pace in International Environment Policy. 2020. Available online: https://ec.europa.eu/environment/international_issues (accessed on 1 October 2020).
24. Gladkaya, L.I.; Shalyapina, A.S. International experience and cooperation of Ukraine in the field of environmental protection. *Cult. Black Sea Peoples* **2013**, *254*, 70–73. Available online: http://dspace.nbuv.gov.ua/handle/123456789/92129 (accessed on 10 August 2020).
25. Environmental Protection Agency. Technical Review Guidelines for Environmental Impact Assessments in the Tourism, Energy and Mining Sectors. 2017. Available online: https://www.epa.gov/international-cooperation/technical-review-guidelines-environmental-impact-assessments-tourism (accessed on 21 August 2020).
26. European Commission. A European Green Deal. 2019. Available online: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en (accessed on 11 August 2020).
27. European Commission. European Research Area Corona Platform. 2020. Available online: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/covid-19 (accessed on 1 September 2020).
28. EURACTIV. LEAKED: Full List of Delayed European Green Deal Initiatives. 2020. Available online: https://www.euractiv.com/section/energy-environment/news/leaked-full-list-of-delayed-european-green-deal-initiatives (accessed on 16 September 2020).
29. Kumar, N. *Towards a Policy Agenda for Achieving SDGs in South Asia, Social Development and the Sustainable Development Goals in South Asia*; Khemka, N.M., Kumar, S., Eds.; UNDP: New Delhi, India, 2019; pp. 146–170. [CrossRef]

30. Wu, J.; Wang, X.; Zhong, B.; Yang, A.; Jue, K.; Wu, J.; Zhang, L.; Xu, W.; Wu, S.; Zhang, N.; et al. Ecological environment assessment for greater mekong subregion based on pressure-state-response framework by remote sensing. *Ecol. Indic.* **2020**, 117. [CrossRef]
31. Werner Florian, A.; Gallo-Orsi, U. *Biodiversity Monitoring for Natural Resource Management. An Introductory Manual*; GIZ: Eschborn/Bonn, Germany, 2016; p. 35.
32. Bacon, E.; Williams, M.D.; Davies, G. Coopetition in innovation ecosystems: A comparative analysis of knowledge transfer configurations. *J. Bus. Res.* **2020**, *115*, 307–316. [CrossRef]
33. Bulmash, B. Green anarchism: On environmentalism and hierarchical domination. *Int. J. Green Econ.* **2019**, *13*, 139–145. [CrossRef]
34. Planko, J.; Chappin, M.M.H.; Cramer, J.; Hekkert, M.P. Coping with coopetition—Facing dilemmas in cooperation for sustainable development: The case of the Dutch smart grid industry. *Bus. Strategy Environ.* **2019**, *28*, 665–674. [CrossRef]
35. Rahmani, S.; Haeri, A.; Hosseini-Motlagh, S.-M. Proposing channel coordination and horizontal cooperation in two competitive three-echelon reverse supply chains. *Int. Trans. Oper. Res.* **2019**, *27*, 1447–1477. [CrossRef]
36. Smertenko, P.S. EUREKA Program as One of the European Programs of Scientific and Technical Cooperation. Available online: https://www.civic-synergy.org.ua (accessed on 21 October 2020).
37. Manzanedo, R.D.; Manning, P. COVID-19: Lessons for the climate change emergency. *Sci. Total Environ.* **2020**, *742*, 140563. [CrossRef] [PubMed]
38. Gaura, V.K.; Sharmac, P.; Sirohid, R.; Awasthie, M.K.; Dussap, C.-G.; Pandey, A. Assessing the impact of industrial waste on environment and mitigation strategies: A comprehensive review. *J. Hazard. Mater.* **2020**, *398*, 123019. [CrossRef]
39. Liu, L.; Zhu, J.; Zhang, Y.; Chen, X. An optimal pollution control model for environmental protection cooperation between developing and developed countries. *Int. J. Environ. Res. Public Health* **2020**, *17*, 3868. [CrossRef]
40. Muhamma, S.; Long, X.; Salman, M. Short communication COVID-19 pandemic and environmental pollution: A blessing in disguise? *Sci. Total Environ.* **2020**, *728*, 138820. [CrossRef]
41. Cheval, S.; Mihai Adamescu, C.; Georgiadis, T.; Herrnegger, M.; Piticar, A.; Legates, D.R. Observed and potential impacts of the COVID-19 pandemic on the environment. *Int. J. Environ. Res. Public Health* **2020**, *17*, 4140. [CrossRef]
42. El Zowalaty, M.E.; Young, S.G.; Järhult, J.D. Environmental impact of the COVID-19 pandemic—A lesson for the future. *Infect. Ecol. Epidemiol.* **2020**, *10*. [CrossRef]
43. Developing Horizon Europe. Available online: https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme_en (accessed on 1 October 2020).
44. UNDP. Boost—An Accelerator for Social Impact Innovation with a Mission to Reimagine, Renew and Recover from Covid-19. Available online: https://boostimpact.org (accessed on 1 October 2020).