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Developing International Collaboration Indicators in Fisheries Remote Sensing Research to Achieve SDG 14 and 17

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Abstract: Remote sensing technology significantly contributes to fisheries management and marine ecosystem preservation. The development disparities among countries create gaps that hinder sustainable fisheries and ecosystem protection. Assessing progress and efforts across regions and countries is crucial for sustainable development. Effective measurement methods are used to identify shortcomings, guide academic development, and strengthen partnerships. Tracking and highlighting partnership achievements is challenging due to the difficulties in quantification. The objective of this study is to create indicators for evaluating the community of international academic cooperation. We analyzed and examined the trend in national efforts and international partnerships before and after the Sustainable Development Goals (SDGs) were released in 2015 using bibliometric methods and bibliographic information from the Web of Science (WoS). The results show that tracking the progress and evolution of international collaborations in fisheries remote sensing research can be facilitated by employing quantitative indicators that measure international cooperation among coauthors, institutions, and countries. Additionally, the number of partnerships in each country displays a significant relationship with the country's level of national development. A comparison of indicators developed by actors with different orientations can be used as a strategic reference for developing partnerships among countries. Academic research in developing countries that rely heavily on fisheries plays a critical role in preserving life below water (SDG 14). The achievement of this SDG can be enhanced through global partnerships (SDG 17).

Keywords: SDGs; indicators; partnership; bibliometric; fisheries; remote sensing

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1. Introduction

Research on innovation and sustainable development has flourished in recent years [1], but developing countries still struggle to implement comprehensive sustainable development science [2–10]. Developing countries have fewer, smaller, and less funded research institutions than developed countries [11–14]. Past research has shown that utilizing strategic planning processes leads to improved performance in sustainable development [15]. Good cooperation is also one of the key strategies that can effectively enhance local knowledge capabilities, establish long-term engagement relationships, and share research results [16–18]. This strategy also provides the funding, training, and technology necessary to move toward a sustainable future involving practical collaboration [19–21]. Therefore, 20 years following the proposal of the Millennium Development Goals (MDGs) and, subsequently, the Sustainable Development Goals (SDGs) proposed by the United Nations, the goals serve as a priority for the international community [22]. Nevertheless, academic gaps remain [23–29]. As a result, the academic community is actively exploring fisheries issues to promote sustainable development and food security [29]. Past research has noted that national economies limit scientific development in some developing countries [30–32]. In the face of such issues, opportunities have arisen to improve the goals and directions of MDG 8 (to develop a global partnership for development) and SDG 17 (to promote partnerships to achieve the goals) [33,34]. Partnerships are critical for sustainable fisheries. In particular, we must ask how international collaboration in global science, technology, and innovation can be strengthened through multilateral collaboration to achieve professional knowledge transfer to best assist developing countries [35–37]. To effectively assess the extent of international academic partnerships across countries, fields, and institutions, it is crucial to strengthen the quantitative science regarding these relationships. To that end, objective bibliometric analysis is a good option [38].

Citation analysis indicator development is one of the most commonly used research methods in bibliometric studies [39–41]. For example, the h-index metric is valuable for expressing a researcher's scientific output. This indicator is based on the number of publications, citations, and essential papers for a given researcher, as well as his or her self-citation status, and it is used to quantify the scientific achievements of researchers [42]. In addition, citation impact indicators are based on the number of papers published and cited [43–45]. However, the factors that can be quantified are not limited to individuals. The number of research groups, research institutions, countries, or journals can also be quantified [46–48]. Citation analysis indicators have played an essential quantitative role in scientific research, and they have attracted attention from various fields in the past few decades and have been extensively studied [44,46]. However, the number of publications is not necessarily related to international collaboration, and citations may not reflect the exchange of information or methods; thus, they may not indicate international collaborations or partnerships. To confirm other relationships, a more reasonable and realistic approach would be to analyze the international composition of coauthors. In particular, some issues with significant sustainable needs or international disputes concerning the performance of countries in international collaboration or partnership deserve specific attention and need to be evaluated based on fair indicators to highlight the countries' efforts and growth. Notably, the characteristics of fisheries are closely related to society, culture, and the economy.

In recent years, corporate social responsibility has received international attention. Fisheries are also among the issues most deserving of attention. The benefits of fisheries include eliminating poverty and creating a sustainable bioeconomic approach. Fisheries are also related to several sustainable development issues, such as food security, health, marine education, economic growth, innovation, consumption and production patterns, marine resources, and ecology, covering SDGs 1, 2, 3, 6, 8, 9, 12, and 14. Because of the spatial specificity of fisheries, global problems may exist in oceans, rivers, or lakes [49]. Regardless of how much sustainable effort is dedicated to a single stock, if a country develops resources in an unsustainable way, it could impact the global sustainability of the fishery stock. Remote sensing detection technology is crucial for strengthening fisheries management and the sustainable development of fisheries. Developed countries (such as the United States, France, and Japan) have invested abundant resources in applying remote sensing detection technology in fisheries management and have obtained excellent research results [50–55]. Due to these developed countries' efforts, many free online resources are available to developing countries [56–58]. In this study, collaboration, coauthors, and coordination are regarded as having the same meaning [59]. Collaboration is a good choice for many developing countries with abundant fishery resources.

Nevertheless, collaboration could also be limited by budgets, human resources, and technology gaps, and the relevant research costs could be too high. The gap between developed and developing countries has long been a research focus of scientists [50,60–62]. Compared with on-site, high-cost test ship research, exchanging satellite telemetry data or technology is a relatively straightforward approach to international collaboration.

Because of the characteristics mentioned above as well as the importance of fisheries remote sensing research and partnerships, as emphasized by the MDGs and SDGs, this research hopes to overcome the current bottlenecks of the quantitative indicators used to measure international collaboration by applying bibliometrics.

Based on the importance of partnership strength in fisheries remote sensing research, publication trends are used to quantify the strength of international partnerships in this research field. Bibliometric research methods are used to determine the scope of assessments, analyze information, and establish different indicators at different scales (national, institutional, and individual author or author group scales). Regarding all metrics analyzed in this study, we consider the "between countries" and "publication periods over 20 years" characteristics to examine the efforts and growth of countries occurring over the two study periods (those for MDGs and SDGs) from different perspectives. A bibliometric approach is used to quantitatively assess international partnerships. The research method can be applied in various fields and can be used to examine the direction of improvement in various areas related to the MDGs and SDGs. Therefore, this study uses the most widely used and authoritative database of research publications and citations to access scientific datasets. Then, author, institution, and country data are extracted from bibliographic data to establish indicators by quantifying and comparing different countries' contributions to fisheries remote sensing research. Finally, this study highlights and discusses the growth of countries in the two different periods of the MDGs and SDGs.

To effectively assess international academic partnerships, strengthening quantitative analysis is crucial. The research objective of this study is to develop indicators to evaluate the global academic collaborative network. We use bibliometric methods and data from the Web of Science (WoS) to analyze the changes in national and international partnerships before and after the SDGs were released in 2015.

2. Materials and Methods

Bibliometric research first emerged in the late 19th century as an objective scientific method for understanding and studying the nature and trends of scientists' behaviors and academic developments by analyzing formal publications [63,64]. The scope of bibliometrics entails the examination of the relevance and impact of published works. Bibliometric analysis can be used to assess research trends, the most relevant topics in a research corpus, and the collaborative networks formed among different authors [65–70]. In recent years, bibliometrics has been used in mainstream country-level analyses of development capacity and scientific and technological policy [71–75]. This trend has led to expanded bibliometric data collection in regard to various countries, research institutions, and scientific fields and the development of indicators as an essential basis for formulating or reviewing policies [76]. The "publish or perish" mentality has profoundly influenced scientists' publication behaviors, and in their academic careers, they face enormous pressure to publish [77,78]. Bibliometrics is a valuable research method for analyzing and understanding applied science [79]. Overall, most scientists strive to publish valuable research results in their academic reports [80]. In addition to increasing the academic voice of individuals and achieving the effect of responding to and influencing policies, these academic reports record each participant's basic information, which can be further used in bibliographic measurements and to establish indicators.

2.1. Research Materials

A two-step research procedure was used for data collection: a scoping review and a bibliometric analysis that covered all aspects of the research field. Then, after retrieving the relevant works from the WoS database, based on the search string, a bibliometric analysis was performed. In terms of language, only articles published in English were considered. This restriction is a possible limitation. However, English will likely continue to be the international language of science [81]. We believed that not including gray literature would not affect indicator accuracy. By collecting the articles found in our search, this research can assist in comprehending the reports of world-class fisheries sustainability research via WoS. Additionally, it can identify the geographical distribution of research gaps.

In this study, the literature from WoS was analyzed. We quickly searched and filtered articles with the advanced search function of WoS [82]. The search string used was the following: TS = (fishery) AND TS = (remote sensing) AND PY = (2000–2021). On 18 January 2022, bibliometric data from 532 articles were collected. The authors of these articles were from 76 different countries worldwide. Information on the relevant authors regarding their institutions, countries, and research publications was retrieved from the database for follow-up analysis.

2.2. Bibliographic Indicators

A collaborative network analysis of coauthor relationships was performed to explore the links formed by academic collaboration, the home countries of authors, and the specific authors of individual articles. First, basic bibliometric statistics were analyzed, and then, the four bibliographic indicators developed in this study were used to quantify national efforts as well as partnership network relationships and growth, as explained below.

Indicator 1: The national authorship counting indicator (NACI) is expressed as follows:

$$\text{NACI} = \sum_{i=1}^{m} \frac{an_i}{tn_i}$$

where m is the sum of the articles published by the target country, tn_i is the sum of the authors of article i, and an_i is the sum of the authors of the i-th article published by the target country.

Indicator 2: The international collaboration indicator based on country (ICIC) is expressed as follows:

$$\text{ICIC} = \sum_{i=1}^{m} cn_i/\text{y}$$

where m is the sum of the articles published by the target country and cn_i is the sum of other countries associated with the i-th article.

Indicator 3: The international collaboration indicator based on institutions (ICII) is expressed as follows:

$$\text{ICII} = \sum_{i=1}^{m} on_i/y$$

where m is the sum of the articles published by the target country and on_i is the sum of collaborating institutions in other countries for the i-th article.

Indicator 4: The international collaboration indicator based on authors (ICIA) is expressed as follows:

$$\text{ICIA} = \sum_{i=1}^{m} pn_i/y$$

where m is the sum of the published articles by the target country and pn_i is the sum of authors contributing to the i-th article from other collaborating countries. y is the publication year divided into the 2000–2014 and 2015–2021 periods; thus, y is equal to 15 years and 7 years, respectively.

2.3. Growth Rate of the Bibliographic Indicators

$$Growth\ rate(\%) = \frac{(x_i - x_j)}{x_i}$$

where x_i and x_j represent any indicator values for the 2000–2014 and 2015–2021 periods, respectively.

2.4. Human Development Index by Country

This research is based on the 2021/22 Human Development Index (HDI) "https://report.hdr.undp.org/ accessed on 21 September 2023)" published by the U.N. Development Programme. The HDI summarizes a country's gross national income and average statistics regarding living standards, such as life expectancy and average years of education. The HDI divides countries into four levels: very high human development (0.8–1.0), high human development (0.7–0.79), medium human development (0.55–0.70), and low human development (less than 0.55). The country-level HDI classifications of very high, high, medium, and low are used in this study. The 76 countries included are listed in Table 1 based on their development levels.

Table 1. Countries by HDI level. (The HDI classifies countries as very high ★, high ◆ medium •, and low ◣).

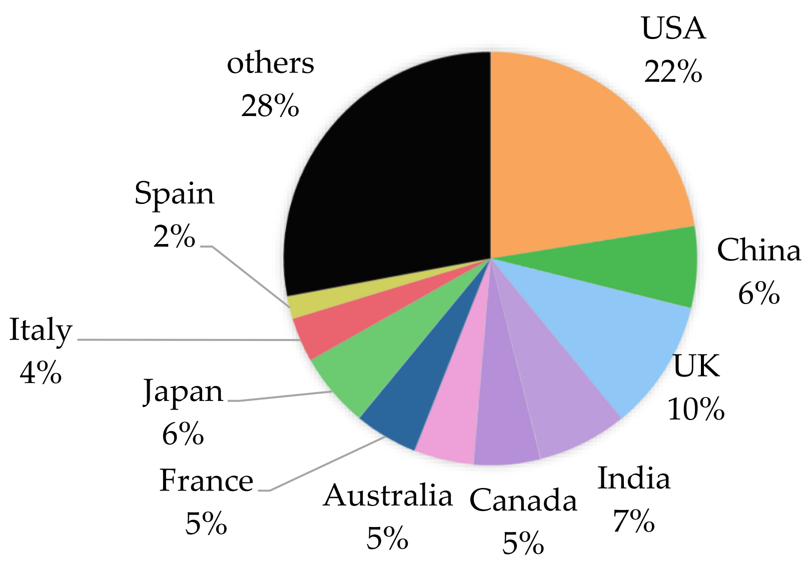
Very High ★ (N = 36)		**High ◆ (N = 18)**	**Medium • (N = 14)**	**Low ◣ (N = 8)**
Argentina	Australia	Algeria	Bangladesh	Cote Ivoire
Austria	Belgium	Brazil	Cambodia	Gambia
Canada	Chile	China	Cameroon	Senegal
Czech Republic	Denmark	Costa Rica	Ghana	Madagascar
Finland	France	Ecuador	India	Malawi
Germany	Greece	Egypt	Iraq	Mauritania
Iceland	Italy	Fiji	Kenya	Tanzania
Japan	Malaysia	Indonesia	Kiribati	Yemen
Netherlands	New Zealand	Iran	Morocco	
Norway	Oman	Jordan	Myanmar	
Poland	Portugal	Mexico	Namibia	
Qatar	Russia	Panama	Vanuatu	
Saudi Arabia	Singapore	Peru	Vietnam	
South Korea	Spain	Philippines	Zambia	
Sweden	Switzerland	South Africa		
Taiwan	Turkey	Sri Lanka		
UK	United Arab Emirates	Thailand		
Uruguay	USA	Ukraine		

3. Results

3.1. Overview of the Growth in National Publications by Countries

Figure 1 shows the total proportion of published articles on fisheries remote sensing research conducted in the MDG (2000–2014) and SDG (2015–2021) periods. This analysis reveals that the United States, which accounted for the highest proportion of MDG-related publications during this period, displayed a slight downward trend in the later period. Additionally, China's share doubled during these two periods. The network analysis diagram on the right side of Figure 2 shows that the SDG network is more complex than the MDG network. The number of countries with international collaborations in telemetry fisheries research rose from 52 to 68, an increase of approximately 30.8%. The total number of connections in international collaboration rose from 198 to 1340, an approximately 5.7-fold increase. The number of global collaboration clusters grew from 11 to 14, increasing by approximately 27.3%.

(**a**)



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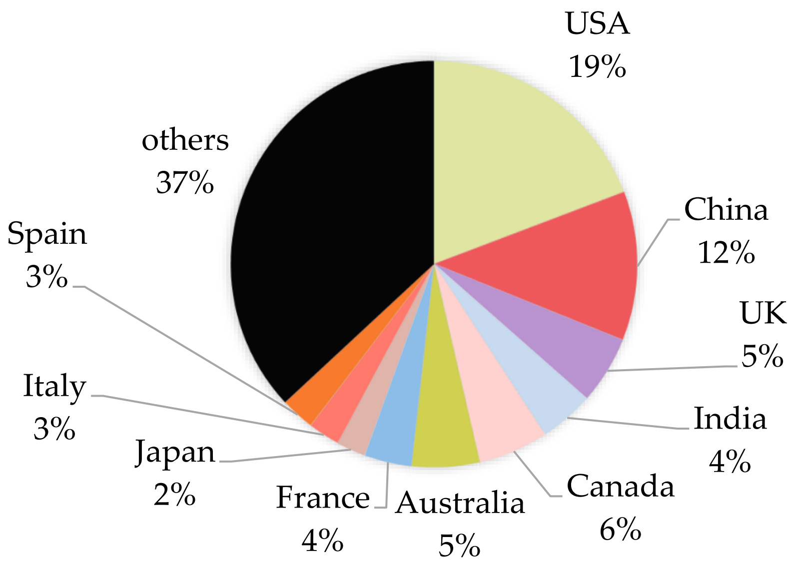

Figure 1. The growth rate of the number of papers published by countries in two periods: 2000–2014 (**a**) and 2015–2021 (**b**).

The number of published articles in each country is the primary unit of statistical analysis used for bibliographic measurement. Figure 3 shows the distribution of contributions to fisheries remote sensing research made by countries in the two periods. Figure 3a shows the number of articles published by countries in the 15 years spanning from 2000 to 2014. Geographically, only nine countries published more than ten articles: the USA (N = 76), the UK (N = 33), China (N = 21), India (N = 21), Canada (N = 20), Japan (N = 20), France (N = 19), Italy (N = 13), and Australia (N = 12). Figure 3b shows the geographical distribution of the number of articles published by countries in the seven years spanning from 2015 to 2021. Fourteen countries had more than ten articles published (in order): the USA (N = 108), China (N = 67), Australia (N =36), the UK (N = 32), Canada (N = 29), India (N = 27), France (N = 19), Spain (N = 15), Italy (N = 13), Japan (N= 13), South Africa (N = 13), Taiwan (N = 13), Indonesia (N = 11), and Brazil (N = 10).

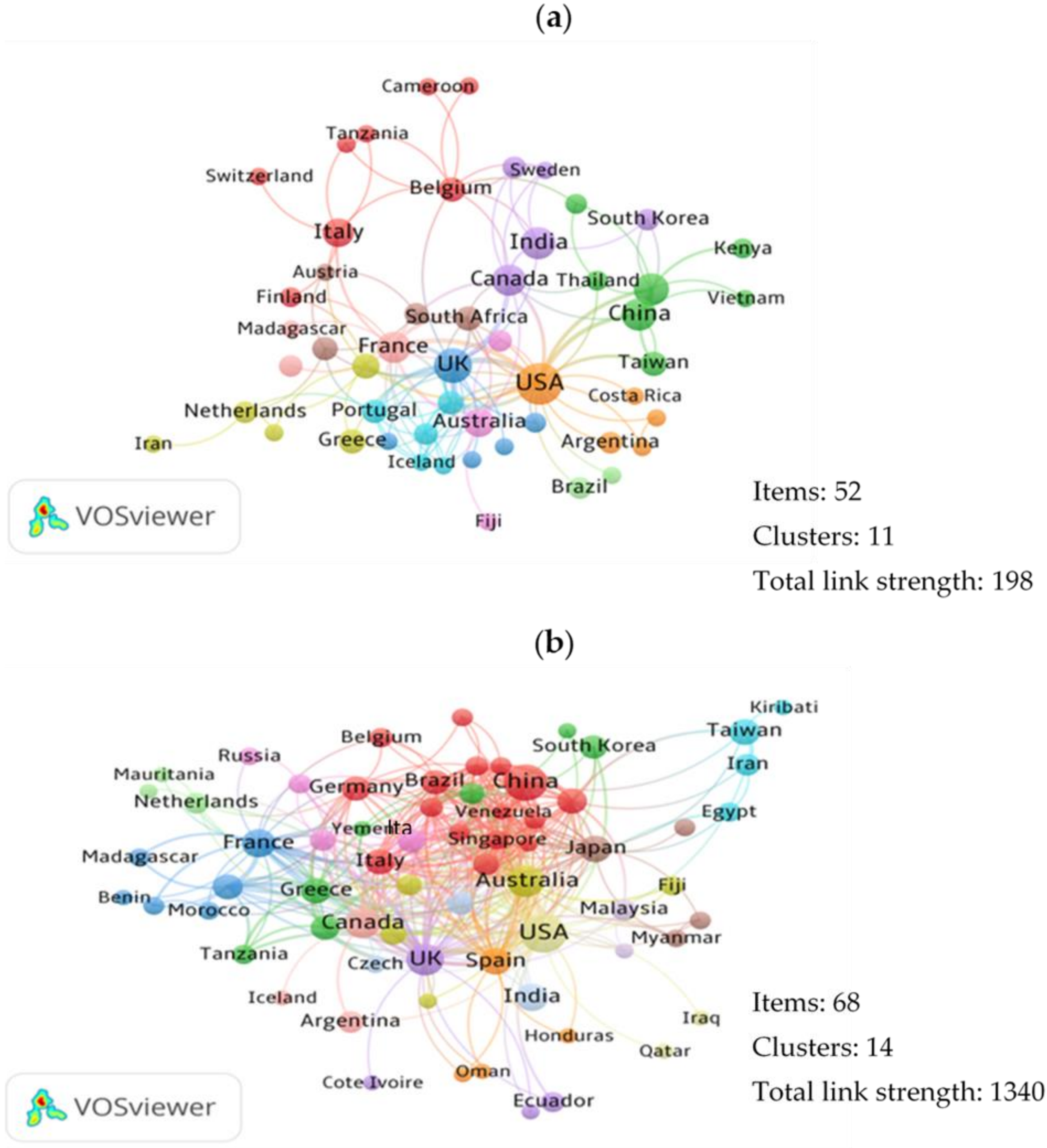

Figure 2. The collaboration network map for the 2000–2014 (**a**) and 2015–2021 (**b**) periods.

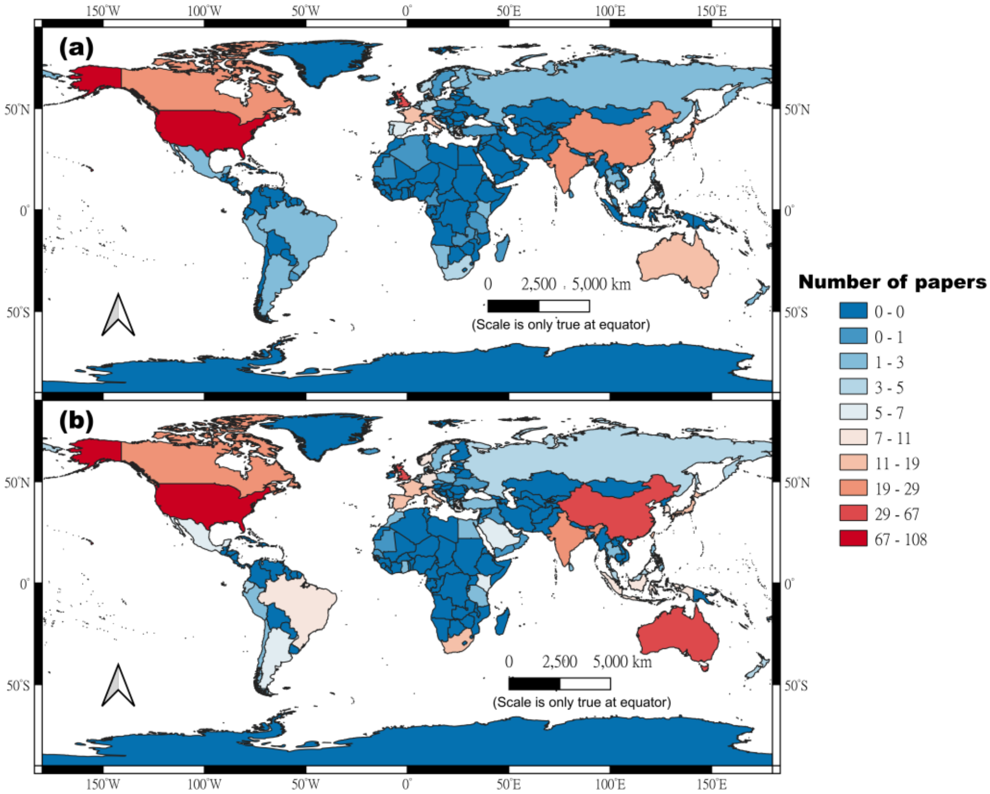

Figure 3. Map of the geographic distribution of the number of articles published by countries in two periods: (**a**) 2000–2014 and (**b**) 2015–2021.

Figure 3 reveals the geographical distribution of the number of articles published by countries during the two periods. The development of remote sensing technology in the Western Hemisphere during the MDG period was significantly higher than that in the Eastern Hemisphere, mainly occurring in North American and European countries near the sea. More than 20 articles were published in countries such as China, Japan, and India in the Eastern Hemisphere. In addition, Australia produced a relatively high number of research results. Most countries in the Eastern Hemisphere still needed to catch up to those in North America and Europe during this period. During the SDG period, in the Western Hemisphere, the research performance of North American and European countries was still ahead of that of other countries. However, many countries in the Eastern Hemisphere significantly increased the number of national publications. Thus, the publication trends in the two hemispheres were relatively balanced. In addition, as shown in Figure 3, some countries in South America rose in terms of the number of contributions during the SDG period. Furthermore, in European countries, the number of publications significantly increased in many cases. Moreover, the number of published articles in countries in the Eastern Hemisphere, such as Taiwan and Japan, increased significantly.

Further analysis of the data for the two periods indicates three different types of country characteristics. Regarding the first type, the number of countries that published more than ten articles in the second period increased significantly from that in the first period. The United States was the country with the highest number of published articles. The number of articles published by China significantly increased, and the number of articles published by other countries, such as Australia, Spain, South Africa, Taiwan, Indonesia, and Brazil, also increased significantly. Among them, the three countries with the highest growth rates were Brazil (233%), China (219%), and Australia (200%), which are equally divided into the very high and high development classes.

The second type includes countries that had fewer publications in the second period than in the first period, such as the United Kingdom (−3%), the Philippines (−33%), Japan (−35%), and Greece (−40%). These four countries showed negative growth. In addition, 13 countries had zero publications in the second period, thus showing 100% negative growth. These countries were Algeria, Austria, Cambodia, Cameroon, Costa Rica, Fiji, Finland, Madagascar, Malawi, Namibia, Panama, Uruguay, and Zambia, apart from Australia, Costa Rica, Fiji, and Finland. The other nine countries are listed as lagging science and technology (S&T) countries.

The third type comprises 31 countries that published the same number of publications in both periods; among these countries, only France (N = 19) and Italy (N = 13) were highly developed. Moreover, 16 countries are listed as lagging S&T countries. Additionally, 31 countries displayed a consistent contribution but with a lower publication volume in the second period. Among this country type, Indonesia displayed the most pronounced trend. The number of articles published in the first period was 0, and even though the number of articles published in the second period reached 11, the growth rate was 0%. Figure 3 shows the changes in the number of articles published by the contributing countries.

3.2. Collaboration and Growth among Dedicated Researchers in Each Country

This study uses the NACI indicator to measure the effort and growth in national fisheries remote sensing research during each of the two periods. The results are shown in Figure 4, where we illustrate the top 20 countries, the countries ranked 21–39, and the limited-growth countries.

The top 20 countries are listed in Figure 4a, which shows that the NACI of these countries (such as Iceland, Poland, Kenya, Indonesia, and Sweden) was small prior to 2015. Some countries provided no prominent assistance (such as Tanzania, Sri Lanka, and Bangladesh). China, Spain, Taiwan, South Korea, and other countries notably increased their NACI since 2015.

Countries that ranked 21–39 established a specific basis for their NACI prior to 2015. such as the United States, India, Canada, the United Kingdom, and Australia. These countries had a high NACI from 2000 to 2014. Thus, even with a continuous NACI increase after 2015, the growth rate is less than three times that prior to 2015. In addition, the NACI of 17 countries showed negative growth during these two periods (Figure 4c). These countries are divided into two categories. The countries in the first group (e.g., Belgium, the Netherlands, the Philippines, and Finland) had a far lower NACI in the 2015–2021 period than they had in the 2000–2014 period. The countries in the second group (such as Algeria, Austria, Cambodia, Cameroon, Costa Rica, Iraq, Madagascar, Malawi, Mauritania, Namibia, Panama, Uruguay, and Zambia) did not publish any relevant research since 2015.

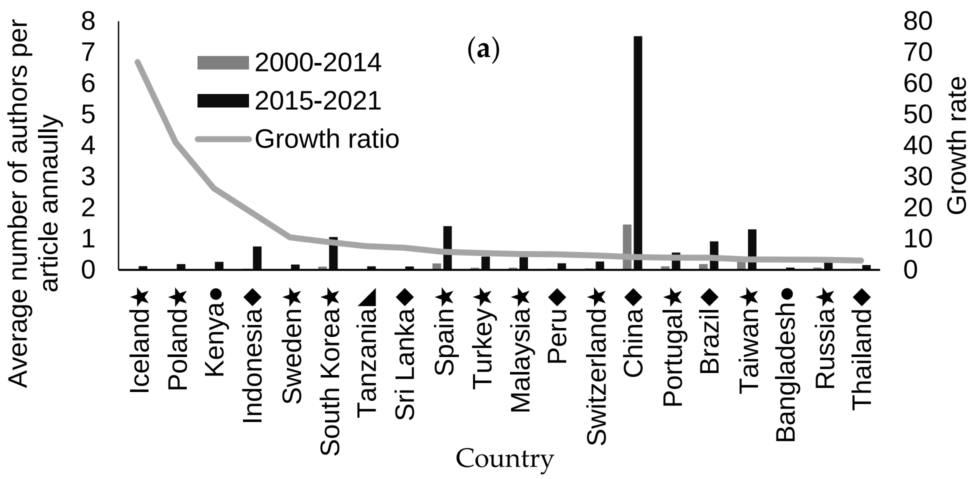

Figure 4. *Cont.*

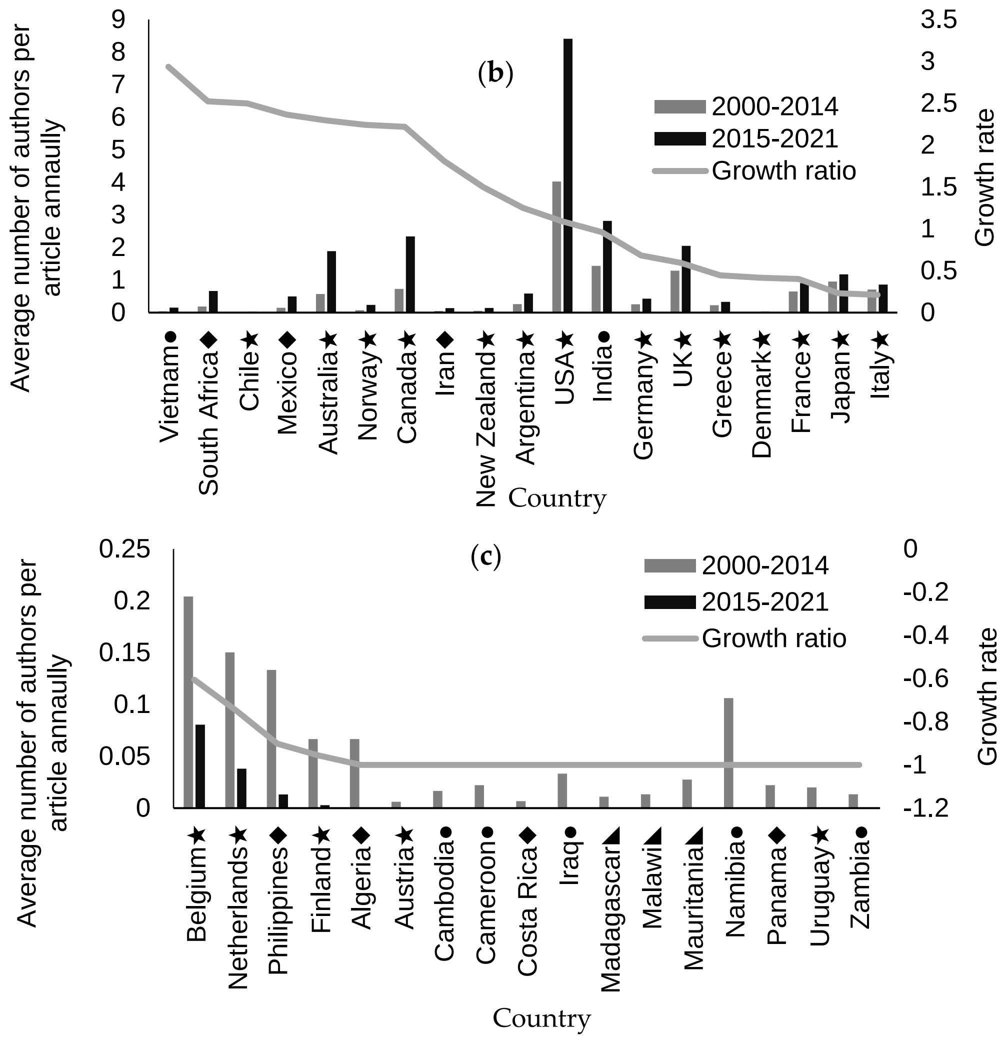

Figure 4. The national authorship count indicator before and after the SDG period and growth rates: (**a**) top 20 countries, (**b**) countries ranked 21−39, and (**c**) negative-growth countries (note: the HDI classifies countries as very high ★, high ◆ medium ●, and low ◢).

3.3. Overview of the Growth of International Academic Collaboration

The ICIC indicator is used to quantify the cross-border collaboration of and growth in the world's major fisheries satellite telemetry countries. The results are shown in Figure 5. Based on different growth scenarios (significant development, slight increase, and negative growth), we present the following results.

The top 20 countries are presented in Figure 5a. The results show that these countries made only a tiny contribution (such as China, Portugal, South Africa, and Canada) or no significant contribution before 2015 but have significantly increased their contribution since 2015. The top 10 are dominated by countries with small contributions prior to 2015. Notably, countries with only minor contributions but that engaged in a wealth of cross-border collaboration in the later stage are still mainly distributed in the top 10 in this ranking.

The countries ranked 21–32 are mainly countries with apparent international collaboration in 2015, such as the United States, Australia, the United Kingdom, and France. These countries provided high contributions from 2000 to 2014. Thus, even if international collaboration continued to increase after 2015, it is still challenging for the growth rate to exceed 2.5 times (Figure 5b) that prior to 2015, as it did in other countries.

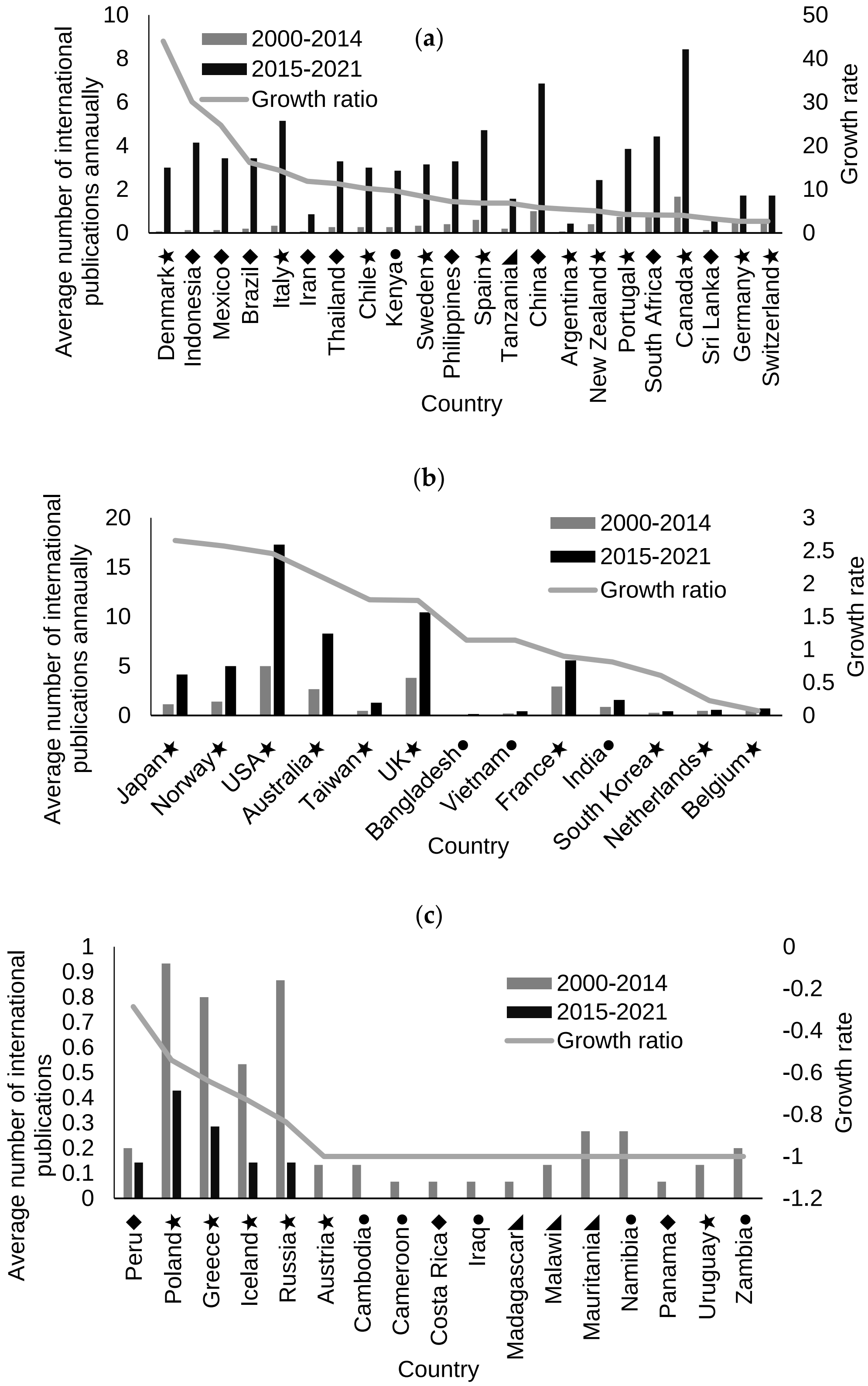

Figure 5. The international collaboration indicator before and after the SDG period and growth rates: (**a**) top 20 countries, (**b**) countries ranked 21−32, and (**c**) negative-growth countries (note: countries are classified by the HDI as very high ★, high ◆ medium •, and low ◢).

Additionally, 17 countries showed negative growth during these two periods (Figure 5c). These countries can be subdivided into two categories. The countries in the first group (such as Peru, Poland, Greece, Ireland, and Russia) engaged in some international collaboration from 2000 to 2014, but their scope of international collaboration declined after 2015. The countries in the second group also engaged in some international collaboration from 2000 to 2014 but had no international collaboration in this field after 2015.

3.4. Overview of the Collaboration Status and Growth in International Institutions

Figure 6 shows the analysis results for the ICII indicator. The figure shows the growth rates and academic achievements of countries in conjunction with institutions from other countries over the two periods under study. The countries in the first group contributed little to the ICII in the early stage (the average annual number of collaborative institutions was 0.3) but have significantly increased their contributions since 2015. These countries are among the top 10 in terms of growth. Figure 6a shows the top 20 countries in terms of ICII growth. Internationally collaborating institutions in the United States, France, Australia, Canada, Italy, Spain, China, South Africa, and Norway made small contributions in the period from 2000 to 2014. Based on the degree of country efforts needed to expand the level of international collaboration among institutions, these countries show approximately 37- to 11-fold growth after 2015.

The second group consists of Japan, the UK, and India. From 2000 to 2014, several institutions cooperated internationally (the average annual number of collaborative institutions was approximately 1.3). Although these countries engaged in more multinational collaborations with institutions from 2015 to 2021, the rankings of these collaborating countries based on this index fell to 21, 22, and 27. As shown in Figure 6b, which ranks all the countries that displayed collaboration growth in the second period, the impact of the effort level in the first period on the indicator greatly decreased, and the most important impact occurred in the first period. Figure 6c shows the countries with negative growth during these two periods. Notably, Zambia and Namibia displayed medium growth, Australia exhibited very high growth, and Malawi displayed low growth.

(**a**)

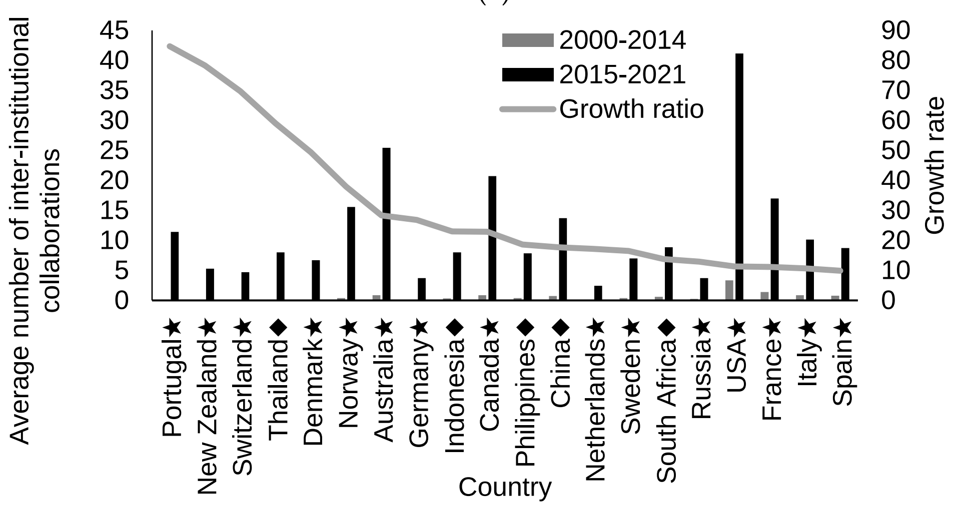

Figure 6. *Cont.*

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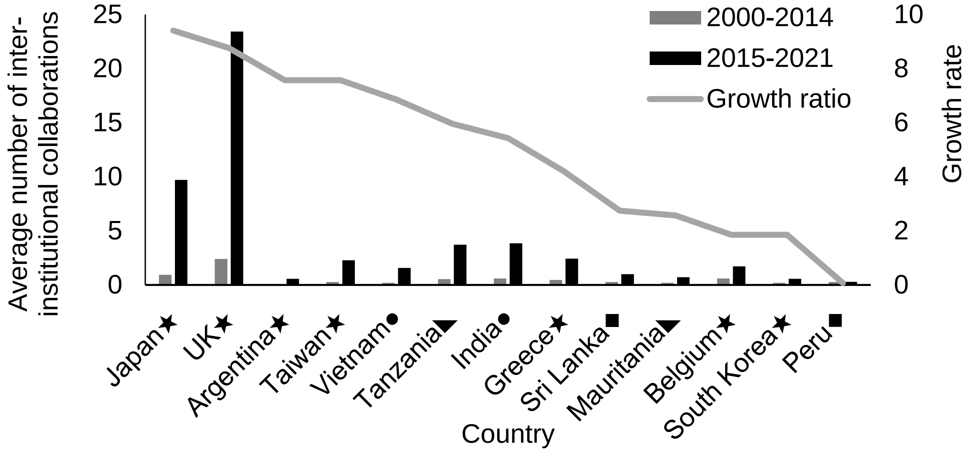

(**c**)

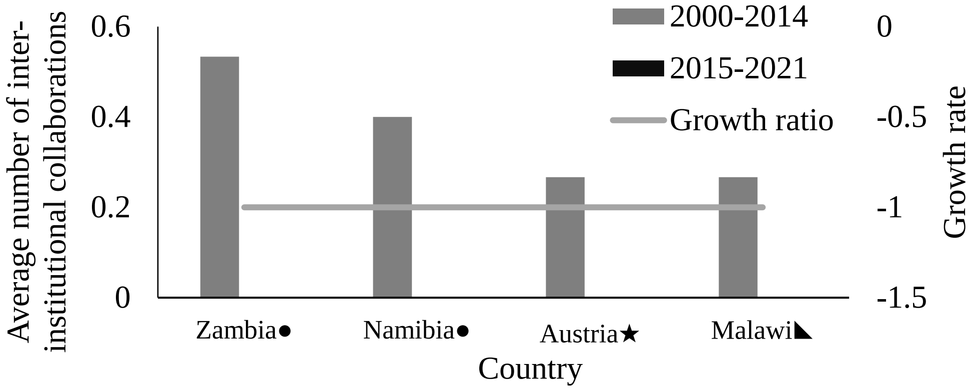

Figure 6. The interinstitutional collaboration indicator before and after the SDG period and growth rates: (**a**) the top 20 countries, (**b**) countries ranked 21−33, and (**c**) negative-growth countries (note: countries are classified by the HDI as very high ★, high ◆ medium •, and low ◣).

3.5. Overview of the Growth in International Coauthorship

This study also quantified the academic outcomes and growth rates of cross-country author collaborations in two stages using the ICIA indicator (Figure 7). The figure is divided into three parts in sequence for clarity.

The first group of countries includes those that did not significantly contribute to the ICIA in the early stage (the average value is 0.11) but with significantly increased contributions since 2015. These countries enter the top 1–5 and 7–8 rankings based on their growth rate, as shown in Figure 7a. Countries belonging to the second group, except for Australia in 6th place, are mainly ranked between 9th and 16th. These countries made a small contribution to the ICIA from 2000 to 2014 (approximately 0.75 people per year), which then grew by approximately 3–44 times the original contribution after 2015. Indonesia is between the first and second groups. Its performance in the 2000–2014 period (0.13) was slightly higher than that of countries in the first group. Notably, its growth rate ranked 10th, but its ICIA in the 2015–2021 period was only 8.57, which is far lower than the ICIA of Canada (27.7), which ranked 9th, and the ICIA of China (16.86), which ranked 11th.

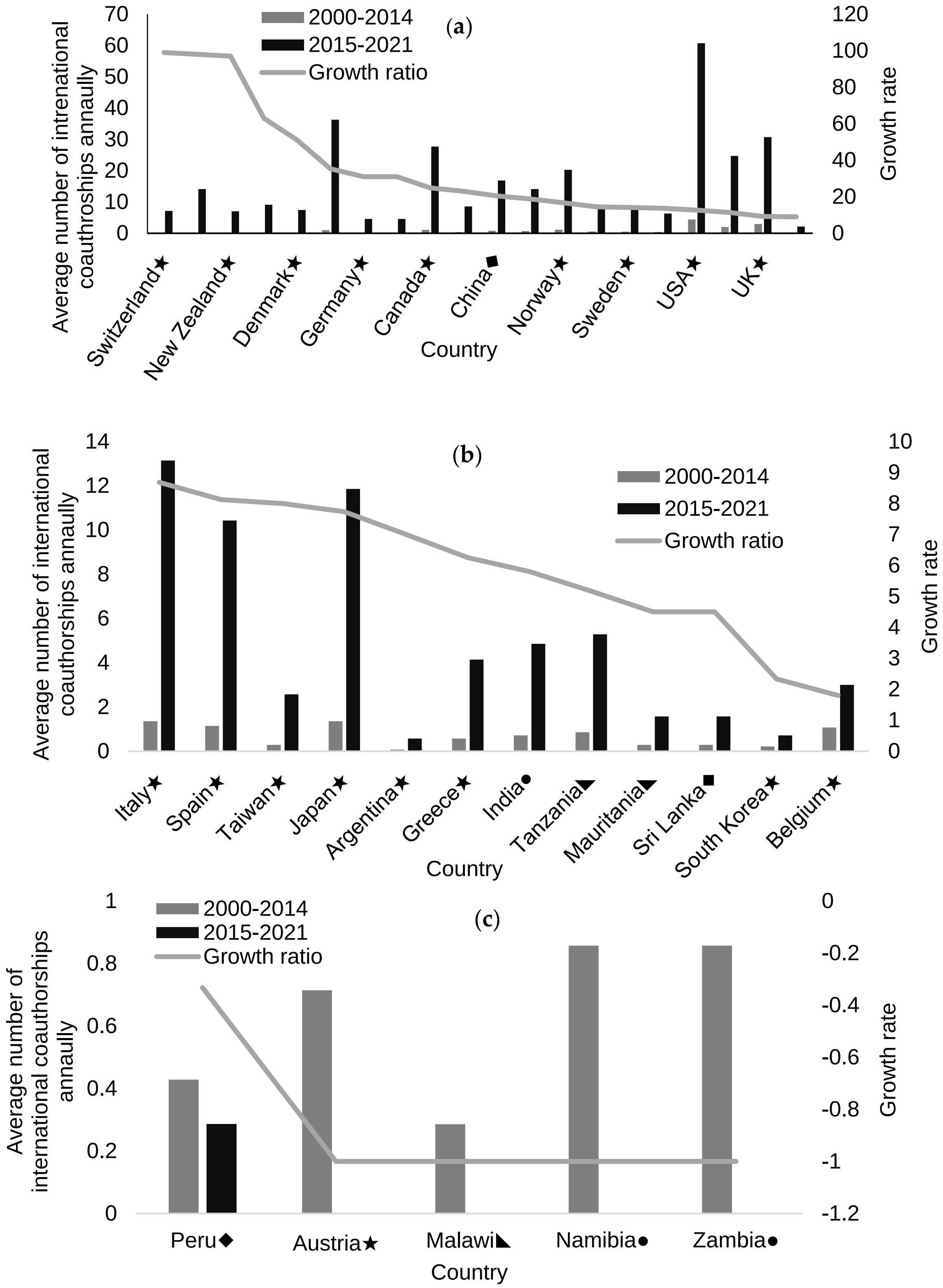

Figure 7. The international coauthorship indicator before and after the SDG period and growth rates: (**a**) top 20 countries, (**b**) countries ranked 21−32, and (**c**) negative-growth countries (note: countries are classified by the HDI as very high ★, high ◆ medium •, and low ◣).

The third group consists of the United States, France, and the United Kingdom. Many researchers in these countries engaged in international collaboration (ICIA of approximately

2–4) in the period from 2000 to 2014. Although these countries had a higher ICIA from 2015 to 2021, they ranked from 18th to 20th based on this index, as shown in Figure 7b. In this figure, all the countries with growth in the second period are ranked 20th or lower. The figure shows that the ICIA effect in the first period was generally relatively low, with a notable increase in the second period. Figure 7c shows the countries with negative growth in these two periods, except for Peru, whose growth was slightly lower in the second period than in the first period. The ICIA of the remaining countries was 0 in the second period.

4. Discussion

Based on WoS, the differences in fisheries remote sensing research collaboration between 2000 and 2021 are compared using four bibliographic metrics. Using the concept of coauthorship found in bibliometrics, the type of international collaboration is distinguished based on the number of countries with which authors are associated, the number of institutions with which authors are associated, and the number of authors. By analyzing the trends in national efforts and international partnerships both before and after the release of the SDGs in 2015, the characteristics of countries with high, low, and negative growth rates are comprehensively analyzed to illustrate the distribution of growth rates and the rankings of countries with different characteristics.

The publication of papers in academic journals demonstrates an important achievement in scientific research and is one of the critical indicators of international collaboration. To assess the output of individual countries, in addition to performing calculations for individual country efforts, the status of international collaboration at different scales (country, institution, author, etc.) needs to be quantified. By developing four indicators, namely, the NPCI, ICIC, ICII, and ICIA, for this research, we specifically meet these requirements. In addition, because each indicator has its own central axis of analysis, they support a comprehensive discussion of the development of international collaboration in individual countries. This study also finds that there may be biases among indicators. For example, the ICIC analysis results are most sensitive to the contribution from 2000 to 2014. If a country made a high contribution during this period, it was not easy to achieve a good growth rate. When encountering such problems, we can refer to the other two indicators of international collaboration (ICII and ICIA) to more objectively discuss a country's contribution. This study also finds that there are significant differences between countries with different levels of development (very high and other). Therefore, before using these indicators for country-to-country comparisons, it is necessary to consider the level of development of countries. Governments supporting SDG actions can increase the capacity of academic research. The volume of many academic studies can be easily quantified, but there has been a lack of quantitative analysis tools for international collaboration in the past [83–86]. In this study, an attempt is made to develop a quantitative tool for measuring international collaboration. After comparing our findings with those of existing research, we find that in terms of international collaboration, Denmark, Switzerland, Germany, the United Kingdom, Australia, the United States, China, South Africa, Brazil, Portugal, Vietnam, and Tanzania are among the countries actively promoting the SDGs [87–93]. Therefore, before using the ICIC for country comparison, it is necessary to consider each country's development level. It is more important to compare countries that have similar levels of development.

The findings of previous research are consistent with those of this study. In addition, the findings of this study indicate that some countries (such as Turkey, Malawi, and Zambia) are committed to promoting the SDGs [88,89], but since the release of the SDGs, they have not published a paper involving international collaboration. After further analysis of the bibliographic data of these three countries, it is found that Turkey's small growth has resulted in the country reaching the stage of domestic collaboration, and the other two African countries, Malawi and Zambia, are in a stage of negative growth, both domestically and internationally. An analysis of domestic collaboration is not conducted within the scope of this article, but future researchers can still use this information to develop indicators of domestic collaboration. Notably, suppose that a researcher wants to look for countries that urgently need assistance in this research field. In addition to looking for countries that have never conducted studies in this field, they can prioritize those countries with negative growth rates. Because negative growth indicates that countries have made contributions in the past, these countries have recently been relatively absent from international collaboration. Researchers can use the indicators in this study to find a country with a high growth rate in the context of international collaboration [94]. The analysis in this study shows that researchers in related fields can identify countries with different growth levels in specific areas and facilitate international academic collaboration based on their needs.

Fisheries remote sensing is one of the critical steps in establishing a sustainable fishery. This study uses four indicators to analyze the growth, stability, and decline in fisheries remote sensing research partnerships in 76 countries worldwide. By studying indicators of international collaboration, in addition to taking stock of the research efforts of each country over the past 22 years, the gap in global partnerships between developed countries and developing countries in terms of implementing the SDGs is identified in this study.

There are often international problems in fishery areas (e.g., oceans, lakes, and rivers) [95]. International collaboration, research, and management are effective means of improving fisheries. Many important fishery-dependent countries are in a developmental stage with limited technical and financial resources. This situation may result in a lack of research data from these countries and hinder the establishment and implementation of fisheries management systems among them. Countries can use the indicators presented in this study to formulate strategies for building partnerships and can measure and track the trend, development, growth, and extent of those partnerships. The indicators developed for this study can also be used to target smaller research areas, making it easier for scientists to target research gaps. Additionally, these indicators can promote long-term partnerships to better measure and manage fishery resources through rolling reviews and adjustments to international collaboration strategies.

To further demonstrate the function of the indicators used in this research to comprehensively analyze development trends and strategies, the growth rates of the ICIC, ICII, and ICIA are compared and discussed. Among the 76 countries included in this study, 38 countries have very high HDI levels, and of the remaining 38 countries, 16 have high, 14 have medium, and 8 have low HDI levels. The countries below the very high level are defined as developing countries for the purpose of analysis. Among the 38 very high HDI countries, only 18 countries experienced growth in the number of countries and the number of institutions they engaged with in international collaboration. Half of the 18 countries displayed a growth rate of less than 0 in terms of the number of countries with multinational collaboration and the number with international institutions, of which 9 were in Europe (Austria, the Czech Republic, Finland, Greece, Iceland, Poland, Turkey, and Russia), 6 were in Asia (Malaysia, Oman, Qatar, Saudi Arabi, Singapore, and the United Arab Emirates), and 3 were in the Americas (Costa Rica, Panama, and Uruguay), showing that partnership is not easy. As illustrated in Figure 8, countries that have developed multinational collaborations with other countries, institutions, and researchers have grown significantly; they include Portugal, New Zealand, Switzerland, Denmark, and Norway. Although the growth rate of partner countries in developed countries such as Portugal, New Zealand, and Switzerland increased only slightly, the number of partner institutions increased significantly. Denmark is different from other countries in that the number of partner countries has significantly increased, whereas the number of partner institutions has grown steadily. However, as shown in Figure 8, the most developed countries have already determined the countries that they want to cooperate with or a specific country with which to expand institutional collaboration. Therefore, the increase in the number of collaborating countries is less noticeable (with a growth rate of approximately 0–15), and the growth rate of institutional collaboration often increases by 70–90%.

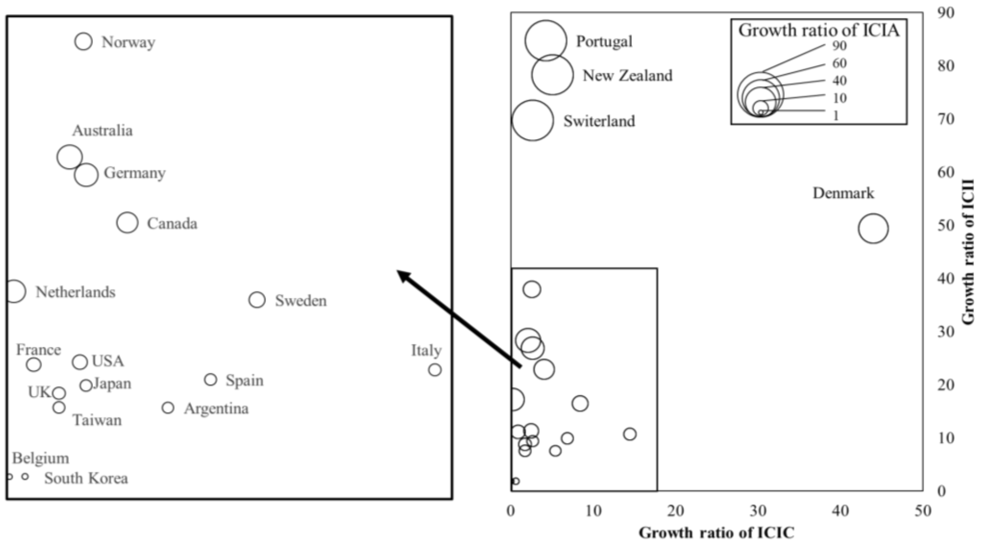

Figure 8. Comparison of the growth rates of cross-border collaborating countries, cross-border cooperating institutions, and the number of cross-border cooperations among very-high HDI countries in two periods: 2000–2014 and 2015–2021.

Among the 38 countries noted as having a high, medium, or low HDI, only 9 displayed an increase in the growth rate of the number of international collaborations and the number of international institutions with which they engage. In this category, there are 29 countries with negative growth for international and interinstitutional collaborations. These include 16 countries in Africa (Algeria, Cameroon, Cote Ivoire, Egypt, Gambia, Ghana, Kenya, Yemen, Madagascar, Malawi, Mauritania, Morocco, Namibia, Senegal, Vanuatu, and Zambia), 6 in Asia (Bangladesh, Cambodia, Iran, Iraq, Jordan, and Myanmar), 4 in South America (Brazil, Ecuador, Mexico, and Peru), 2 in Oceania (Fiji and Kiribati), and 1 in Europe (Ukraine). The number of international collaborations in developing countries is much lower than that in developed countries. For example, Figure 9 shows the growth trend in developing countries. This figure reveals that Thailand and Indonesia are particularly prominent collaborators among developing countries. Except for India, which has a growth rate of less than 1, the other six countries in this group have growth rates of approximately 1–7.

Figure 9 shows that the numbers of collaborating countries and collaborating institutions in Thailand far exceed those in other countries. Thus, the growth rate of collaborating partners in Thailand is also significantly higher than that in other countries. Indonesia, which ranked second, has more partners than Thailand, but the number of partner countries and the number of collaborating institutions are lower than those in Thailand, thus limiting the corresponding growth rates. Figure 9 shows that developing countries, on average, cooperate with two institutions per country. The growth rate of cross-border collaboration displayed in Figure 9 shows that increases in the numbers of collaborating institutions and countries for these countries are conducive to the growth in the number of partnerships.

On the other hand, although Thailand has a high number of cooperating countries, the number of cooperating institutions far exceeds that of other countries. Additionally, the growth rate of international cooperators is significantly higher than that of other countries. Compared with India, the growth rate of the number of collaborating countries is much higher due to the limited growth rate of international collaboration among institutions. Consequently, the growth rate of the number of international partners in India is just above the average level, which is far lower than the growth rate of the number of international partners in Thailand. Figure 9 shows the development trend of developing countries. It reveals that except in Thailand and Indonesia, the ratio of the growth rate of multinational collaborating countries to the growth rate of institutions in most developing countries is approximately one to two. The analysis results show that in addition to seeking support from more countries in the future, increasing the level of international collaboration can be a critical factor in increasing the output of academic achievements and knowledge exchange in many countries.

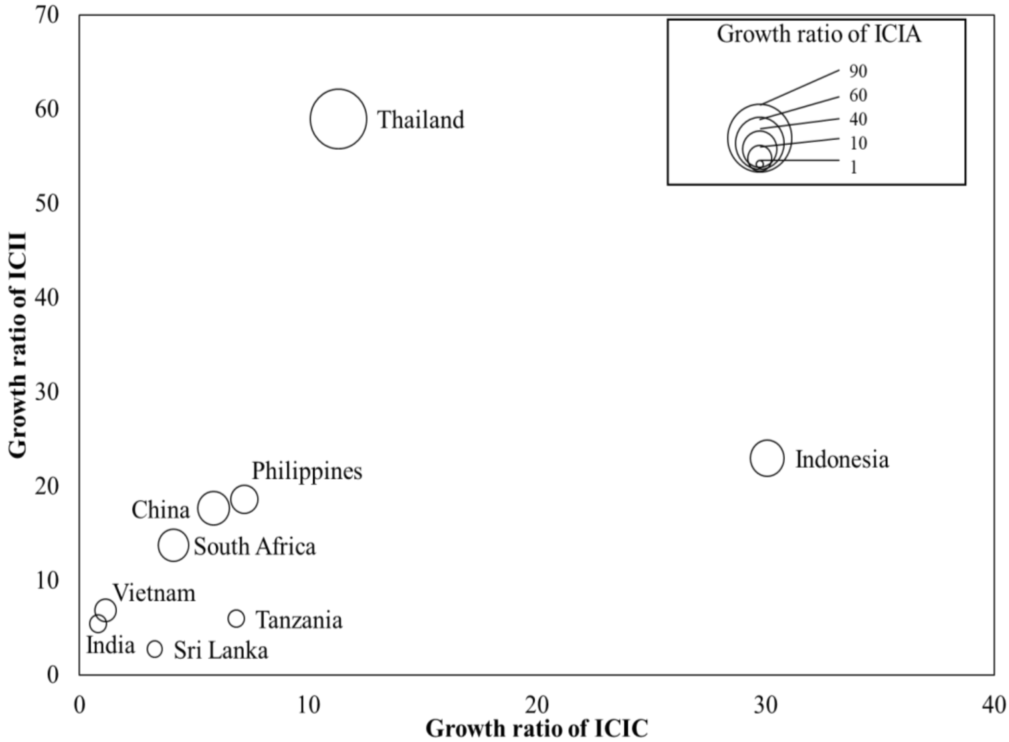

Figure 9. Comparison of the growth rates of cross-border collaborating countries, cross-border collaborating institutions, and number of cross-border collaborations in high-, medium-, and low-HDI countries in two periods: 2000–2014 and 2015–2021.

5. Conclusions

Regarding research partnerships, bibliographic information and metrics are essential for quantifying them. This study has developed quantitative indicators that can be used to examine current and past trends and growth in international partnerships in any field and country. It is important to note that collaboration between authors does not necessarily indicate collaboration between institutions or countries. By comprehensively applying collaboration, gaps in international academic research partnerships can be explored. While this study has limitations, it is essential to consider developing countries' efforts and developed countries' sustainable development accomplishments.

The era of rapid and widespread climate change has introduced a considerable amount of uncertainty. However, global fisheries management and ocean governance are crucial to achieving sustainability. Communication and technology dissemination must be increased in every field and country. Scientific collaboration in developing countries must be further integrated into research activities. Support for Sustainable Development Goals (SDG) varies significantly across countries, from national strategies to monitoring, evaluation, management, and indicator systems. The indicators established in this research can aid in follow-up research by simplifying the understanding of differences in and the rationality of academic collaboration in different contexts.

Additionally, the study can determine the correct timetable for promoting the SDGs and identify obstacles. This study has also highlighted the growth and decline in fishery trends in individual countries. Fisheries serve as a critical source of food security and protein. The results of this study can provide a reference for researchers in various academic fields and guide the management of fishery resources. Developing countries highly dependent on fisheries may need more resources to invest in necessary research. Any partnership aimed at sustainability will help developing countries operate sustainably.

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