Article

Mapping the Shifting Focus in Remote Sensing Literature: Technology, Methodology, and Applications

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Abstract: This paper characterizes the body of knowledge on remote sensing from 1999 to 2021 by employing bibliometric techniques based on the Science Citation Index databases and the Social Science Citation Index of the Web of Science, abbreviated to "SCI" and "SSCI", respectively. A total of 28,438 articles were analyzed from various aspects of the publication characteristics, such as countries, institutes, subjects, journals, and keywords. Dynamic changes in published remote sensing research were examined by segregating the 19-year period into 4 stages. Co-occurrences of keywords from three aspects were evaluated, including technology, methodology, and applications. Results show that "hyperspectral remote sensing", "classification", "monitoring" and "MODIS" in the category of technology have emerged more frequently in recent years, and there are strong co-occurrences of "remote sensing" and "GIS" in the remote sensing technology category. In addition, there was a marked shift from traditional analytical methods (i.e., geostatistics and neural networks) to a variety of emerging methods, such as support vector machines, random forests, and feature extraction. Moreover, research hotspots are identified for remote sensing applications, which have expanded significantly with improvements in technology and methodology. In particular, "water quality", "climate change", and "urbanization" have become popular themes in recent years. Finally, future directions of remote sensing are identified, which would be beneficial for researchers and policy makers.

Keywords: remote sensing; bibliometric method; cooperation analysis; applications

1. Introduction

Observational data and model simulations provide fundamental understanding of various popular topics, e.g., climate change, natural ecosystems, urban settlement, and human health, to support human development [1]. As an important tool for detecting objects and phenomena, remote sensing offers valuable data about the Earth's surface for mapping, change detection, and global analyses [2,3]. Providing multi-temporal data and spatial coverage images, remote sensing has gradually become a leading research method in social development studies [4].

With current temporal and spatial resolutions, remote sensing allows scientists to detect changes over a broad scale and assist decision makers in dynamically evaluating the atmosphere, ocean, and land. Remote sensing is an important data source for monitoring airflow movement and precipitation [5] and supports the application and improvement of relevant algorithms [6,7]. Additionally, remote sensing technologies, such as synthetic aperture radar, can observe the ocean surface and have the ability to extract image information [8,9]. For example, synthetic aperture radar imagery is used in ocean observation to predict, prevent, and clean oil contamination [10]. Moreover, remote sensing is a useful source of data for areas that are inaccessible by ground surveying [11]. For instance, remote

sensing data are frequently used with models to simulate the dynamics of overlying land and its changes at a variety of spatial scales [12]. In addition, multidisciplinary approaches have become mainstream for remote sensing-related studies, such as climate change [13,14], ecosystem services [15], environmental studies [16,17], agriculture [18,19], natural disasters, and so on [20]. Therefore, it is necessary to evaluate the growing body of literature on remote sensing applications. It is useful to explore past, present, and future trends in remote sensing within the context of applications. Academically, studies critically reviewing global remote sensing research have been limited [21]. In particular, a comprehensive overview of remote sensing applications from both quantitative and qualitative perspectives is lacking. In addition, no study has provided a holistic and quantitative review of remote sensing publications by conducting bibliometric analysis and complex network analysis. Therefore, this study aims to fill this gap.

Bibliometric analysis has been widely adopted in quantitative research assessments of academic output. It was defined by Pritchard (1969) as "the application of mathematics and statistical methods to books and other media of communication" [22]. It is an effective tool to quantitatively evaluate scientific and technological output [23,24]. Within this context, this paper aims to explore the evolutionary pathway of remote sensing studies using bibliometric analysis to track past progress and help identify future research directions. The primary objectives of this study include: (1) evaluation of past and current research in remote sensing technology, methodology, and applications; (2) consider publication characteristics, including countries, research institutions, journals, and most cited articles; (3) use keywords to explore dynamic temporal trends in remote sensing applications corresponding to their technology and relative methods; and (4) identify potential directions for future research, contributing to research progress as well as the future development of remote sensing applications.

2. Methodology

2.1. Data Collection

The Web of Science Core Collection provides a variety of records for each publication, including author information, journals names, citations, and institutional affiliations. We mainly searched for articles from SCI and SSCI, published in English from 1999 to 2021. The study used keywords (i.e., "remote sensing *" or "remoting sens * or "remot * sens * or other different forms of "remote sensing") to search and collect research articles. A total of 46,934 pieces of literature were identified through database searches. After excluding 11,960 pieces of non-article literature and another 6536 from title and abstract screening, a total of 28,438 full-text articles were screened for eligibility.

2.2. Impact Factors

The foundation of document research includes publication statistics mainly targeted at published authors, countries, institutions, journals, etc. In this study, the journal impact factor is adopted to measure the influence of publications. The impact factor (IF) is calculated by dividing the citation count of the current year by the number of articles published in the journal during the two preceding years [25]. As one of the most essential tools in bibliometric research, IF is used in this paper to evaluate the relative influence of remote-sensing-related journals. In general, journals with higher impact factors are expected to have more influence than those with lower ones [26]. In this paper, the impact factor of a given journal was retrieved from the 2015 Journal Citation Reports (Thomson Reuters, Philadelphia, PA, USA).

2.3. Content Analysis

Content analysis helps to highlight any form of content by providing quantitative counts on various aspects of the content [27]. Co-word analysis is a key technique in content analysis that maps the associations between words in textual data to analyze emerging research trends and changes between topics [28]. By presenting information in

multi-dimensional graphs, co-word analysis is more effective than other content analysis methods [29]. Hence, co-word analysis was adopted in this study to explore hotspots of remote sensing research by extracting the title, keywords, and abstract of publications from the perspectives of technology, methodology, and applications.

2.4. Social Network Analysis and Data Visualization

A social network is a set of people or groups that are connected with each other. Similarly, collaboration is a common social interaction that highlights relationships among actors, e.g., people or groups of people. The social network analysis (SNA) method has been widely employed in various disciplines [30], such as computer science, natural resources, enterprise management, and land use analysis [31–34]. SNA aims to reflect the centrality of actors and the dynamic interactions among them from a statistical perspective. In this study, SNA was conducted to establish a network with the nodes represented by research papers, keywords, or institutions. Such networks can be used to evaluate the influence of a node by using various measurement metrics, including closest centrality and degree centrality [35]. To analyze complex networks among countries and institutions, we used Bibexcel and Pajerk for data visualization, which have been widely used in previous studies [36].

3. Results and Discussions

3.1. Basic Characteristics of Publications

The Science Citation Index Expanded (SCI-E, 1999–present) and Social Science Citation Index (SSCI, 1999–present) databases from ISI Web of Science were used to compile the literature dataset. A total of 46,934 articles with topics (titles, abstracts, and keywords) containing the following search strings, i.e., "remote * sense *" and "data" were collated on 21 December 2021. Of all publications retrieved from Web of Science, peer-reviewed research articles account for 91%, followed by proceeding papers (4.98%), review papers (3.1%), and others (e.g., book chapters, conference reviews, notes, short surveys, business articles, articles in press, books, letters, and reports). Similarly, English (97.8%) is the most frequently used language, followed by Chinese (1.4%), Portuguese (0.4%), and others. To provide an international perspective, only research articles published in English were further analyzed in this paper, resulting in 28,437 documents analyzed.

### 3.2. Contributions to Publications by Year and Country

The spatio-temporal distribution of all published articles from 1999 to 2021 is shown in Figure 1. In the early years, annual output grew slowly up until a spurt of growth in 2012, with the mean annual growth rate exceeding 10%. The collated publications were mainly contributed by developed countries which account for nearly 60% of total published articles since 2012 (Figure 1). In fact, the 10 most productive countries are mainly distributed across North America and Europe, including 9 highly developed countries. In particular, the United States (U.S.) is the leading country for remote sensing research from 1999 to 2021 in terms of the total number of published articles (10,094, 35.5% of total). China ranks second after the U.S. in terms of number of publications (5360, 18.8% of total). The rapid growth of publications from China is associated with the increasing budget from the National Science Foundation of China (NSFC) since 2002 [37]. A total of 898 papers were published since 2002, which is comparable to U.S. productivity. Germany ranks third, accounting for 8.5% of the total publications. Annual publications from Germany have been increasing steadily. Other top developed countries in terms of publications include the UK (6.2%), France (5.0%), Italy (4.7%), Canada (4.4%), Australia (4.2%), and The Netherlands (3.6%). In addition, it is worth noting that although India had a late start along with China, it has shown rapid growth in recent years. The average annual growth rate in publications in India was 10.7% between 2012 and 2015, exceeding the overall global growth rate.
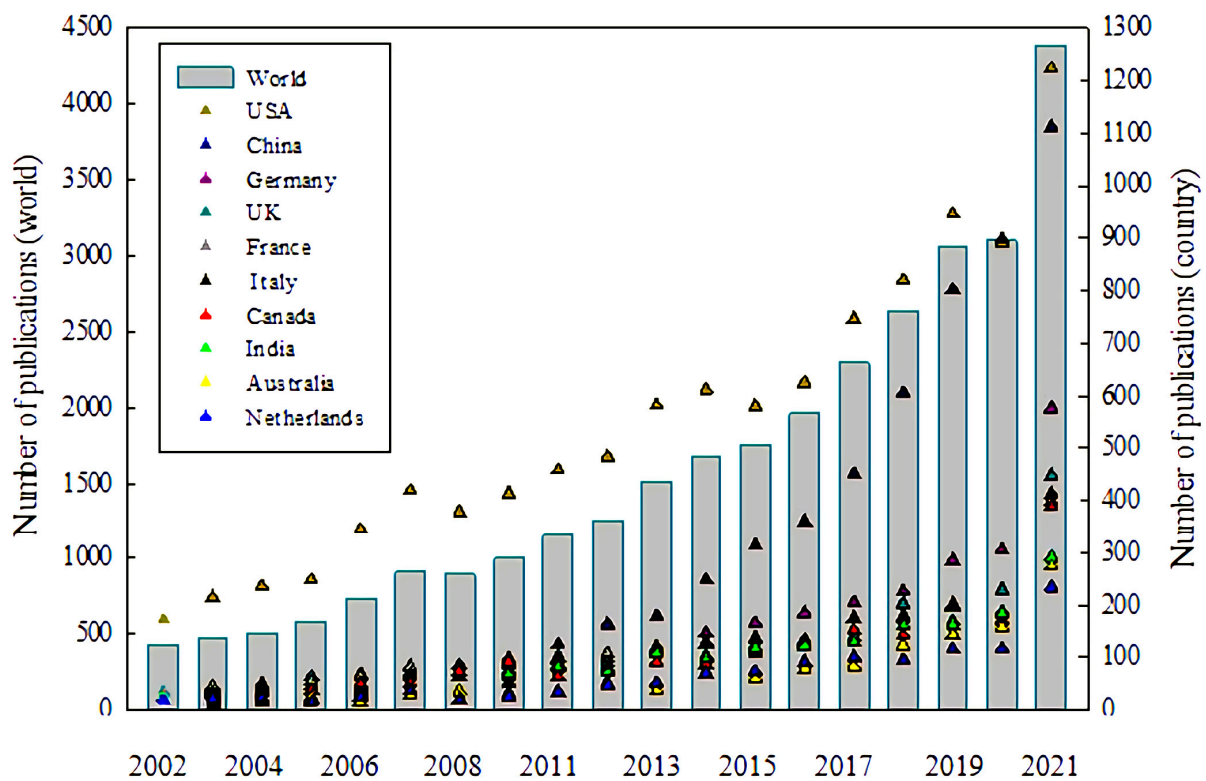
Figure 1. Comparison of publication counts from the top 10 countries and total publication counts globally, 1999–2021.

3.3. Contributions to Publications by Institutes

We applied social network analysis (SNA) to obtain the cooperative relationships among the 30 most productive institutions in the field of remote sensing research during the period 1999–2021 (Figure 2) [38]. Each node represents a different institute, and the size of the node indicates the relative number of publications [39]. Similarly, the line connecting countries represents their cooperation, and the line pattern indicates the number of co-occurrences. Among these institutes, 17 are from the U.S., indicating that the highly productive institutes contribute to the overall leading publications in remote sensing research. In addition, the Chinese Academy of Sciences (CAS) made the largest contribution to the total number of publications with 3677 records, followed by the National Aeronautics and Space Administration (NASA) in the U.S. (1523 records). The 30 productive institutions favorably worked closely with others from the same country (Figure 2), for example, the CAS and Beijing Normal University and NASA and the University of Maryland. It is worth noting that CAS cooperates well with overseas institutes, too. The most significant cooperative relationships are between CAS and the University of Maryland, which have resulted in many collaborative publications.
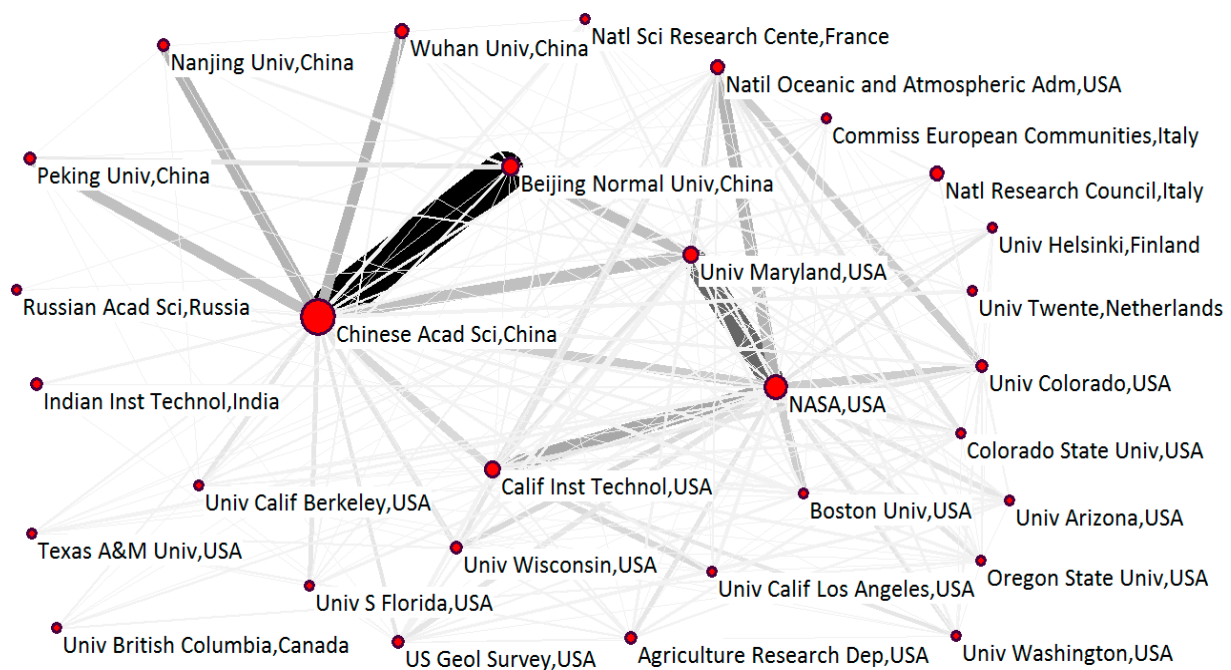
Figure 2. Institutional collaboration according to social network analysis.

3.4. Characterization of Research Areas and Publication Sources

All remote-sensing-related articles were divided into 174 subject categories in the SCI and SSCI databases. Remote sensing is the most popular subject because it is closely related to the key words of this paper (Figure 3). Imaging Science and Photographic Technology ranked second with 7692 records, followed by Environmental Science with 5797 records, and Geosciences with 5308 records. The contribution of the top five subjects accounts for nearly 10% of the total number of publications.

Remote-sensing-related articles are published in 2031 journals. More than 35% of the remote-sensing-related articles are published in the top 20 journals listed in Table 1. *Remote Sensing of the Environment* has the most articles (1754), followed by the *International Journal of Remote Sensing* (1600), and *IEEE Transactions on Geoscience and Remote Sensing* (1555). It is worth mentioning that *Remote Sensing of the Environment* ranks first in terms of the number of articles with the highest IF value (5.88) among these journals. The high IF may be related to the wide scope of the environmental discipline and the broad audience, which includes social scientists, environmental engineers, aerospace engineers, geographers, biologists, and hydrologists. In addition, among the top five most influential journals, *IEEE Transactions on Geoscience and Remote Sensing* (IF: 3.36), *Remote Sensing* (IF: 3.04), and *ISPRS Journal of Photogrammetry and Remote Sensing* (IF: 4.19) are all top journals with high impact factors, covering different aspects of remote sensing theory, technology, and applications. In particular, although *Remote Sensing* was founded in 2009, it has published 3620 articles, and its IF has significantly increased from 2.623 in 2013 to 4.848 in 2020.
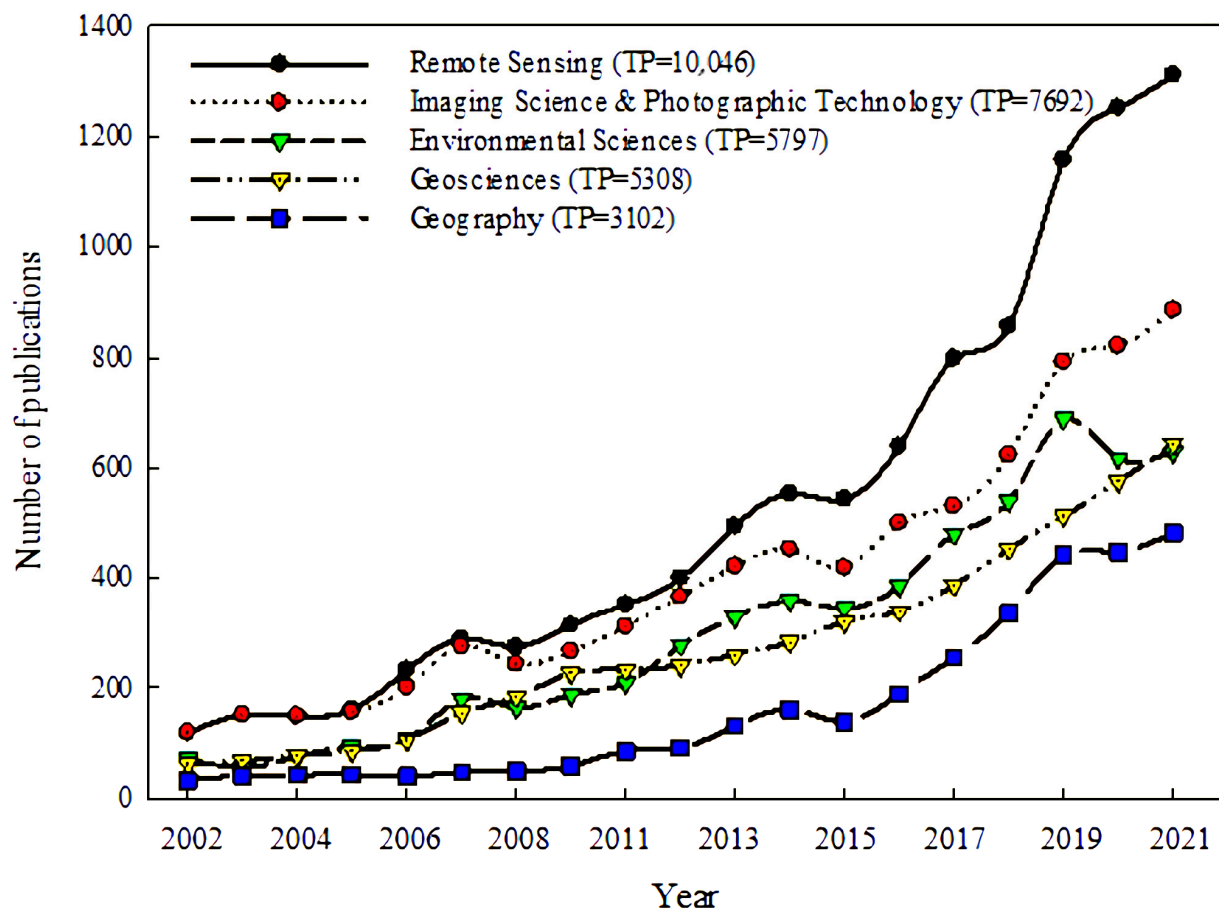
**Figure 3.** The top five subject categories. TP: The total number of publications.

Table 1. The top 20 journals in terms of publication numbers.

Journal Name	TP	TP R (%)	IF2020
Remote Sensing of Environment	1754	6.17	9.085
International Journal of Remote Sensing	1600	5.63	3.151
IEEE Transactions on Geoscience and Remote Sensing	1555	5.47	5.630
Remote Sensing	997	3.51	4.848
ISPRS Journal of Photogrammetry and Remote Sensing	830	2.92	5.994
IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing	557	1.96	4.715
Journal of Geophysical Research-Atmospheres	464	1.63	5.217
International Journal of Applied Earth Observation and Geoinformation	437	1.54	5.933
IEEE Geoscience and Remote Sensing Letters	405	1.42	5.343
Journal of Applied Remote Sensing	389	1.37	1.53
Spectroscopy and Spectral Analysis	267	0.94	0.690
Journal of Hydrology	256	0.90	2.964
Environmental Monitoring and Assessment	239	0.84	3.307
Photogrammetric Engineering and Remote Sensing	226	0.79	1.608
Journal of the Indian Society of Remote Sensing	226	0.79	1.894
Geophysical Research Letters	196	0.69	5.576
Environmental Earth Sciences	187	0.66	2.180
Hydrological Processes	176	0.62	3.783
Sensors	174	0.61	2.928
Journal of Coastal Research	165	0.58	0.589

TP: the total publications of the journal during 1999–2021; %: percentage of the publications of the journal; IF2015: the journal's impact factor in 2020.

4. Research Hotspots

The interconnection network among the top most frequently used keywords in related articles was obtained by using social network analysis tools [40]. The study period was subdivided into four periods to trace the dynamic changes in the remote sensing field. By investigating the co-occurrences of keywords, some topical clusters and their distributions were identified. The evolution of the most frequent keywords during 1999–2021 and the hotspots' development in different stages can be seen (Figure 4). Overall, the number of keywords in the clusters (including remote sensing technology, methodology, and applications) increased exponentially from 2003. Meanwhile, the application scope expanded, transferring from a few clusters (e.g., water, plants, soil, and land) to a much larger number of clusters (e.g., energy, climate, and urbanization). This expansion shows that in recent years, remote sensing applications have been receiving rapidly growing attention with an increasing number of relevant publications. In addition, although remote sensing technology and methodology received little attention in the early years, the development of remote sensing applications has created a massive demand for relevant technologies and methodologies since 2008.
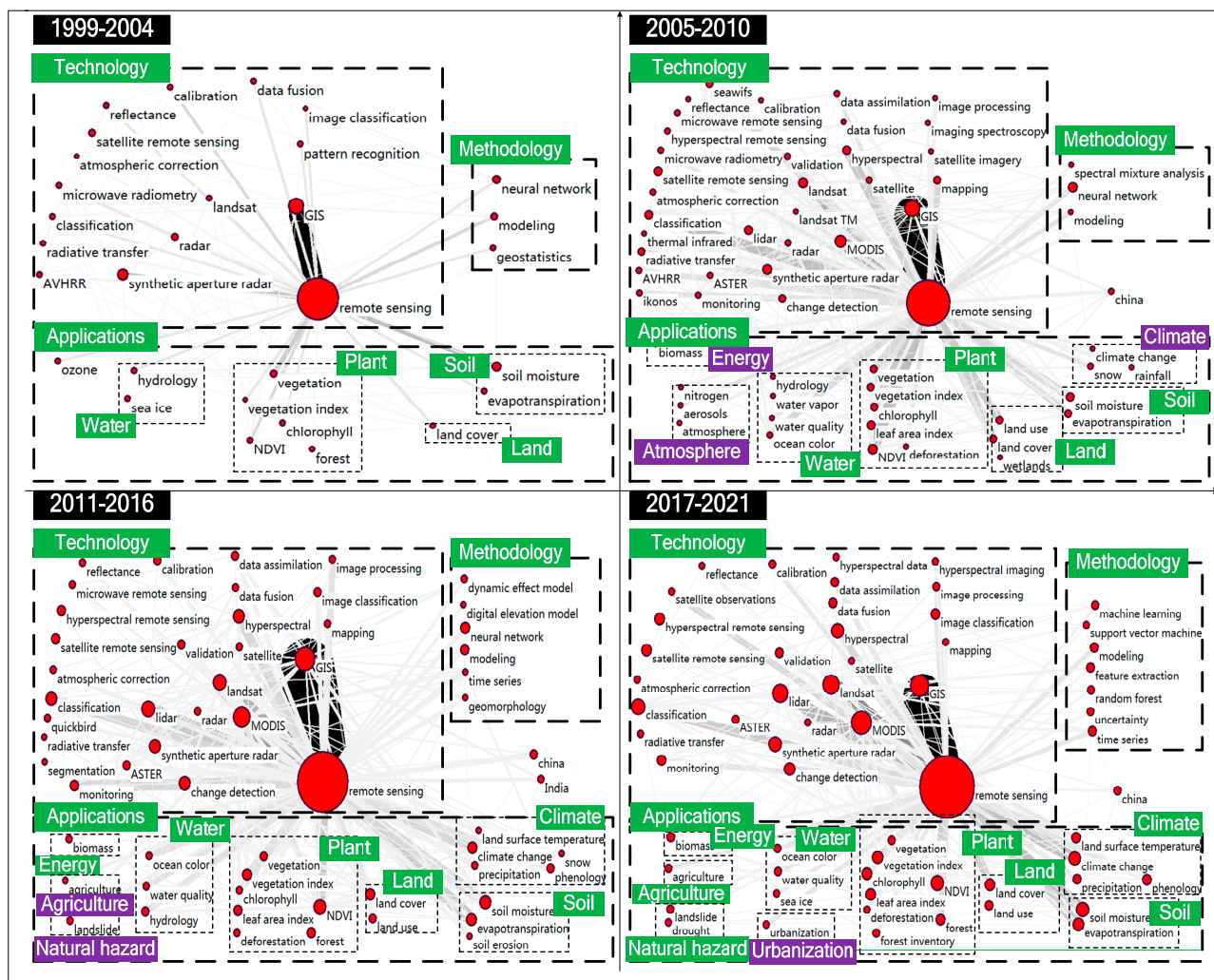
Figure 4. The interconnection network and evolution of keywords in remote-sensing-related publications during 1999–2021. The red dot represents the relative number of keywords. The larger the red dot is, the more frequently the keyword appears in the related literature. The pattern of the grey line presents the number of co-occurrences. The thicker and darker the line is, the larger the number of co-occurrences of keywords that were used by the author.

Optical sensors, the heart of remote sensing systems, are primarily employed in industrial, automotive, electrical, and retail automation to detect the presence of targets or to perform motion detection. Synthetic aperture radar (SAR), on the other hand, is an active earth observation system that may be mounted on airplanes, satellites, spacecraft, and other flying platforms to observe the world continuously and in all weather conditions. It also has a limited capacity for surface penetration. Lidar, an active remote sensing device that uses lasers as the emitting light source and photoelectric detection technology as the means of detection, is a sophisticated detection technique integrating laser technology and contemporary photoelectric detection technology.

Emerging remote sensing technologies are increasingly becoming more accessible thanks to the Digital Earth concept's widespread appeal. Examples include MODIS, which helps scientists understand how the climate is changing globally and how human activity is affecting it; QuickBird, the only commercial satellite in the world with sub-meter resolution; and hyperspectral data, which makes it possible to invert the physical and chemical characteristics of landforms. At the same time, advanced methodologies are widely used in remote sensing research, and machine learning is one of the important tools. Most commonly, random forests (RF), support vector machines (SVM), and artificial neural networks are the well-known algorithms utilized in remote sensing. The high-dimensional issue is somewhat alleviated by the RF classifier. While artificial neural networks attempt to simulate how our brains recognize patterns, supervised learning models (SVMs) can be utilized for regression and classification issues. As a result, it is clear that remote sensing technology and methodologies are evolving quickly and that new application areas are opening up.

Therefore, in recent years, some emerging technologies (i.e., MODIS, QuickBird, hyperspectral data, etc.) and advanced methodologies (i.e., machine learning, support vector machine, random forest, etc.) have been widely used in remote sensing research.

4.1. Remote Sensing Technologies

The overall tendency in emerging technologies (Figure 4) can be used to further understand remote sensing applications with the support of various technologies at different stages. As previous bibliometric research has described, "remote sensing" and "GIS" were two frequently used keywords in remote sensing related publications from 1991 to 2010 [41]. In the past 18 years, it can be observed that there have been strong co-occurrences of "remote sensing" and "GIS" which are applied in 88% of the publications (Figure 4). The integration of remote sensing and GIS has been one of the main development trends in remote sensing technology to provide support for related research [42]. Since 2003, there has been an obvious increase trend in the number of technology types, including MODIS, AVHRR, radar, mapping, data fusion, image classification, etc. The emerging technologies facilitate development of remote sensing applications. For example, since the launch of the Terra satellite in 1999 and the Aqua satellite in 2002, MODIS has provided nearly global coverage for advanced studies of the atmosphere, ocean, and land. Since 2008, the total number of remote sensing technology-related publications has grown exponentially (Figures 4 and 5), which reflects the rapid development of remote sensing technology. A surge in remote sensing technology enables the expansion of its applications as seen in publications during 2008–2013. Technologies, such as "MODIS", "LANDSAT", "LIDAR", "classification", and "hyperspectral", have become leaders in remote sensing (Figure 5). In particular, hyperspectral remote sensing was applied in related research for the first time in 1991, following that of other remote sensing technologies. Since 2003, hyperspectral techniques have been adopted in a wide range of high resolution research, such as road transportation, regional pollution, and urbanization [43,44]. The application of hyperspectral remote sensing is projected to continue growing in the near future.
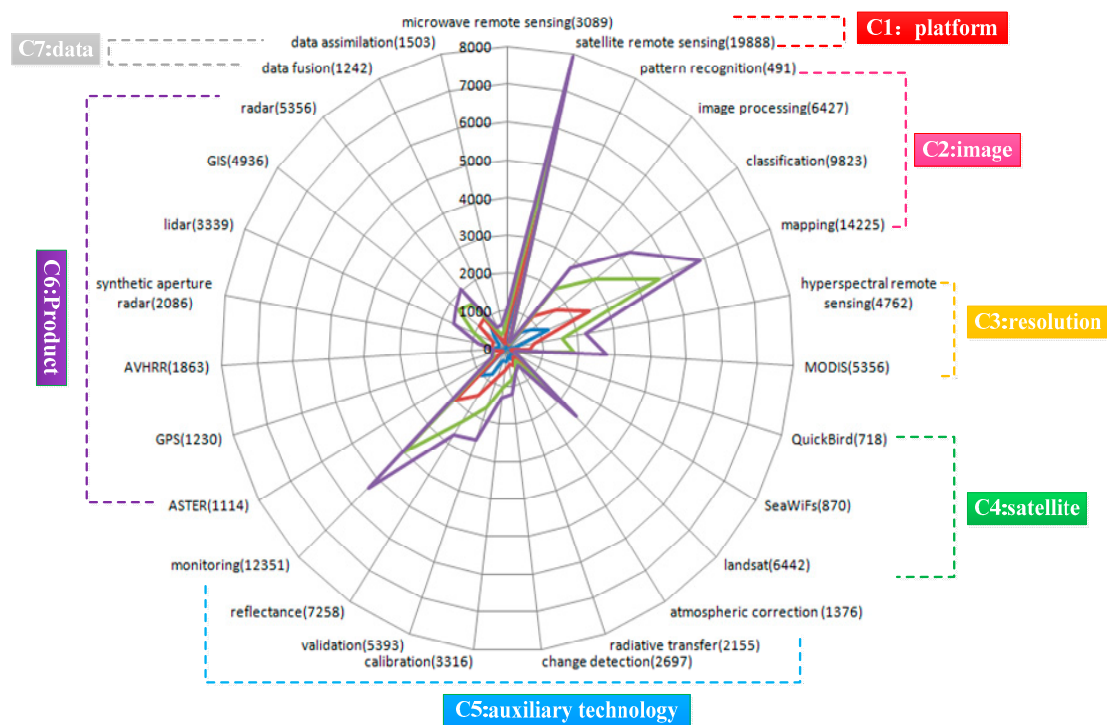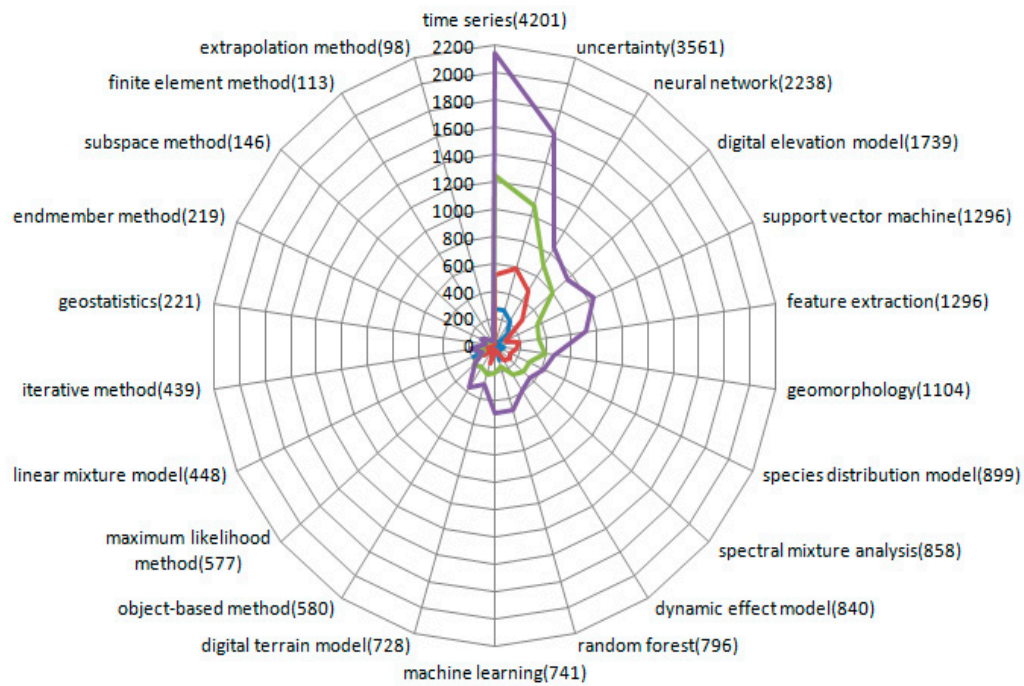
(**A**) Annotation: The blue line represents 1999–2004, the red line represents 2005–2010, the green line represents 2011–2016, the purple line represents 2017–2021.
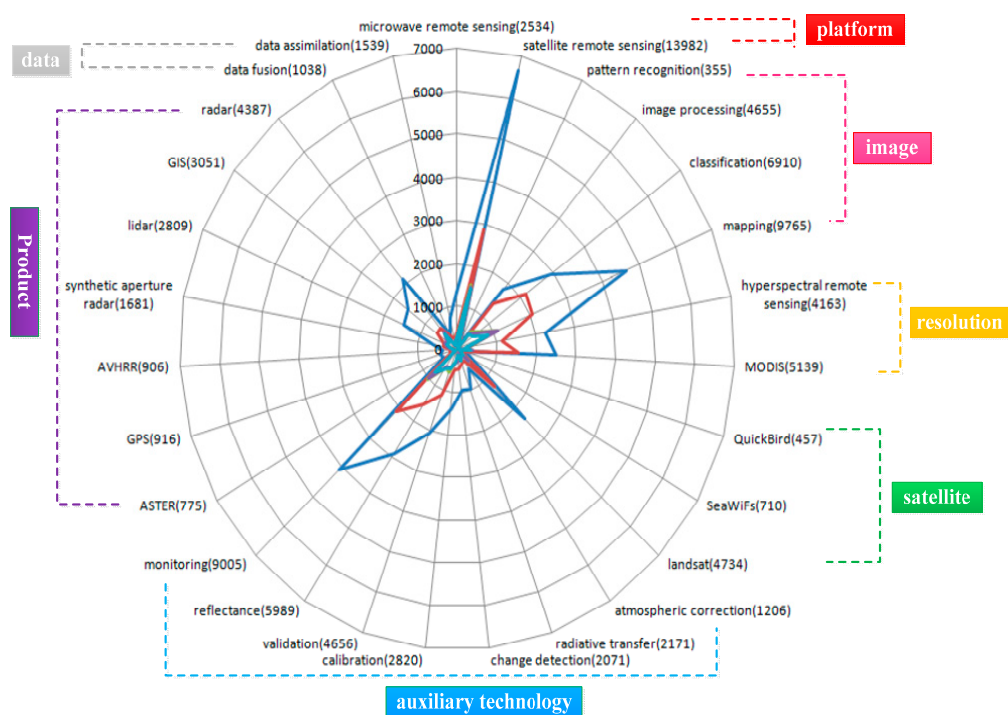
(**A′**) Annotation: The blue line represents the United States, the red line represents China, the green line represents Germany, the purple line represents Britain, and the cyan line represents France.

Figure 5. *Cont.*

(**B**) Annotation: The blue line represents 1999–2004, the red line represents 2005–2010, the green line represents 2011–2016, the purple line represents 2017–2021.
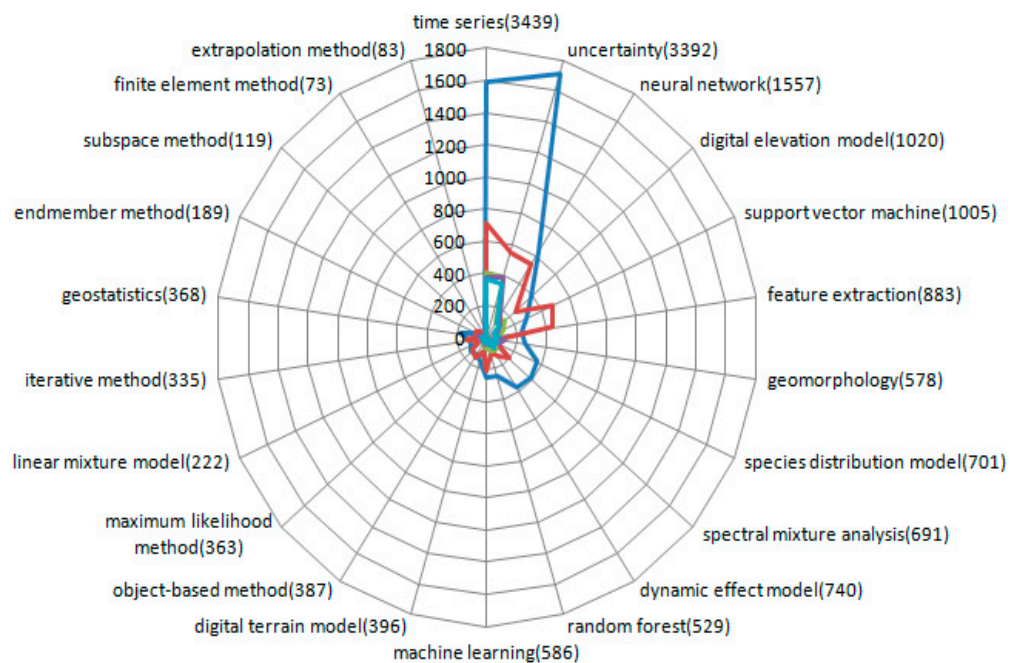

(**B′**) Annotation: The blue line represents the United States, the red line represents China, the green line represents Germany, the purple line represents Britain, and the cyan line represents France.
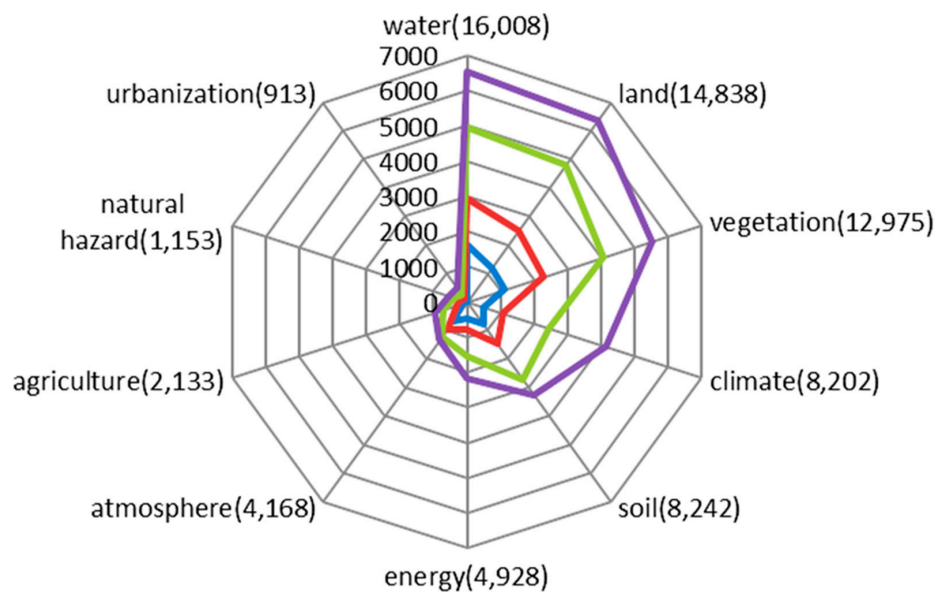
Figure 5. *Cont.*

(**C**) Annotation: The blue line represents 1999–2004, the red line represents 2005–2010, the green line represents 2011–2016, the purple line represents 2017–2021.
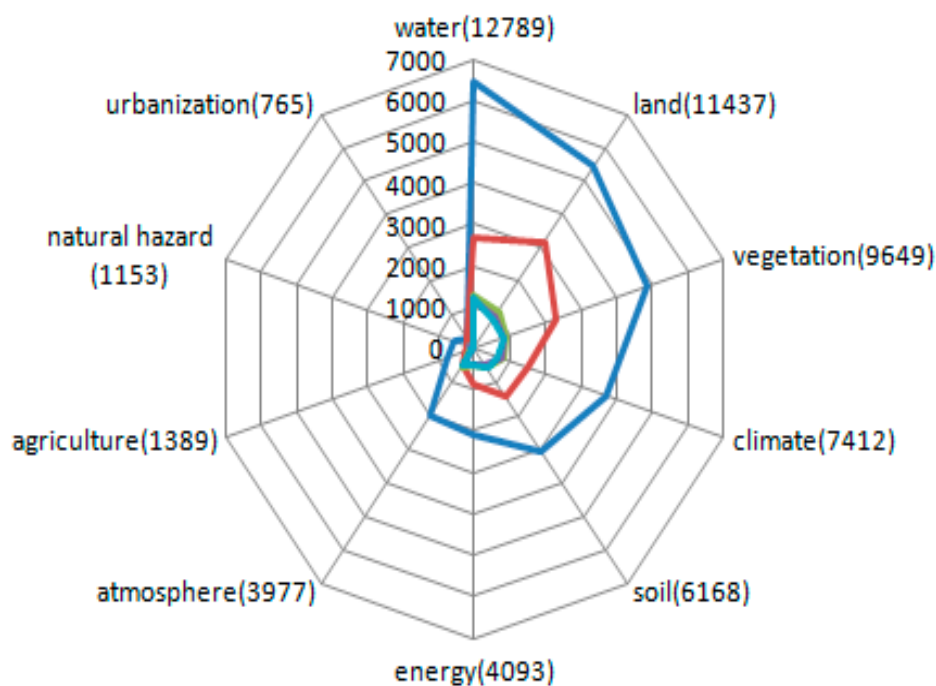

(**C'**) Annotation: The blue line represents the United States, the red line represents China, the green line represents Germany, the purple line represents Britain, and the cyan line represents France.

Figure 5. Distributions of remote-sensing-related publications for the 1999–2021 period. Distributions of remote sensing: (**A**) technology; (**B**) methodology; (**C**) applications in different stages; distributions of remote sensing: (**A'**) technology; (**B'**) methodology; (**C'**) applications in top productive countries.

The top seven clusters relative to stages and countries are further identified in Figure 5. The C1 cluster (satellite/microwave remote sensing) belongs to the remote sensing platform category. The keyword "satellite remote sensing" has the most publications, almost 20,000, accounting for 15% of all the publications with keywords. It indicates that satellite remote sensing plays a vital role in related research, and it was frequently selected as a remote

sensing technology. The C2 cluster (pattern recognition, image processing, classification, and mapping) has the most publications (30,966) among all clusters, which shows that image-related technology was the popular focus of remote sensing technology at different stages. In contrast, data-related technology research in cluster C7 (data fusion and data assimilation) has received little attention. The C3 cluster (MODIS, hyperspectral remote sensing) was frequently used to improve spatial and temporal resolution. The development of hyperspectral remote sensing expands the breadth and depth of related research. In the C4 cluster (QuickBird, SeawiFs, and LANDSAT), LANDSAT was an effective tool for providing a wide range of information in the early research, while application of SeawiFs and QuickBird in ocean optical and commercial remote sensing research began in 1992 and 1999, respectively. Clusters C5 and C6 are close to each other, indicating that the technology products (radar, GPS, lidar, synthetic aperture radar, AVHRR, GPS, ASTER) and auxiliary technology (monitoring, reflectance, validation, calibration, change detection, radiative transfer, and atmosphere correction) are related to each other. This finding also suggests multiple applications in remote sensing technology research.

Differences in research foci among the top five productive countries were also compared (Figure 5). The U.S. was the leading country in the remote sensing technology field with the most publications in each technology-related research. China ranked second with half the number of publications as the U.S., followed by Germany, the UK, and France. Interestingly, Germany, the UK, and France have similar trends in each remote sensing technology research. These top five countries have similar tendencies in research foci relative to the top seven clusters (C1 through C7). However, the U.S. has made great contributions to remote sensing product research (C6) relative to that from other countries. For example, the U.S. accounts for about 50% of the total publications on GIS and remote sensing research globally, indicating the commercial orientation of remote sensing technology.

4.2. Remote Sensing Methodologies

The overall tendencies in remote sensing methodologies are shown in Figure 4. During the first two stages (1999–2007), remote sensing methodology received little attention compared to technologies and applications. This suggests that qualitative research was the main focus in the early years. For example, both themes of real-time and spatial localization information were main research foci before 2008, with little demand for methodology development [45]. However, during the 2008–2012 period, there was a shift from a single method to a wide range of methods, such as dynamic effect models, digital elevation models, neutral networks, time series, and geomorphology. During this stage, a large number of remote sensing technologies were applied in related research. These applications provided support for researchers or managers to regard remote sensing as a dynamic monitoring and management tool [46]. As a result, a variety of related methodologies emerged at this stage. For example, dynamic effect models and time series have been widely used to analyze the tendency of real-time information and dynamic monitoring. During the fourth stage (2013–2021), with the accumulation of environmental data, a new opportunity exists for composite processing and comprehensive analysis of multisource data [47]. Meanwhile, spatial databases and management systems have been established to collect and search big data related to remote sensing. Hence, four emerging methodologies (machine learning, support vector machine, feature extraction, and random forest) have been widely used on cross-subjects, integrated assessments, data fusion, and prediction research in the remote sensing research field.

The increasing number of publications with the keywords "time series" (4210 publications) and "uncertainty analysis" (3561 publications) suggests that these techniques have become common methodologies in the remote sensing field of research (Figure 5). Meanwhile, some advanced methodologies (such as "support vector machine", "feature extraction", and "random forest") received an increasing level of attention with relatively high growth in publications during 2013–2021. In contrast, although "neural network" and "digital elevation model" were developed rapidly during the early years, they have

been less frequently used in recent years with less publication. Furthermore, differences in remote sensing methodologies used among the top five productive countries indicate that the U.S. and China are the two leading countries with the most publications on remote sensing methodology research (Figure 5). However, different countries have partly focused on a selection of remote sensing methodologies. Although time series and uncertainty analysis were the main methodologies for productive countries, there are differences among other advanced methodologies used in remote sensing research by country. For the U.S., there are three main remote sensing methodologies, including the dynamic effect model, spectral mixture analysis, and species distribution model, which were less frequently used by other productive countries. In contrast, China includes another two main remote sensing methodologies (i.e., support vector machine and feature extraction) which were rarely used by other productive European countries. European countries, including Germany, the UK, and France, have similar research foci, primarily time series and uncertainty analysis, while other methodologies were underdeveloped. This analysis highlights significant differences in remote sensing methodologies among the top productive countries.
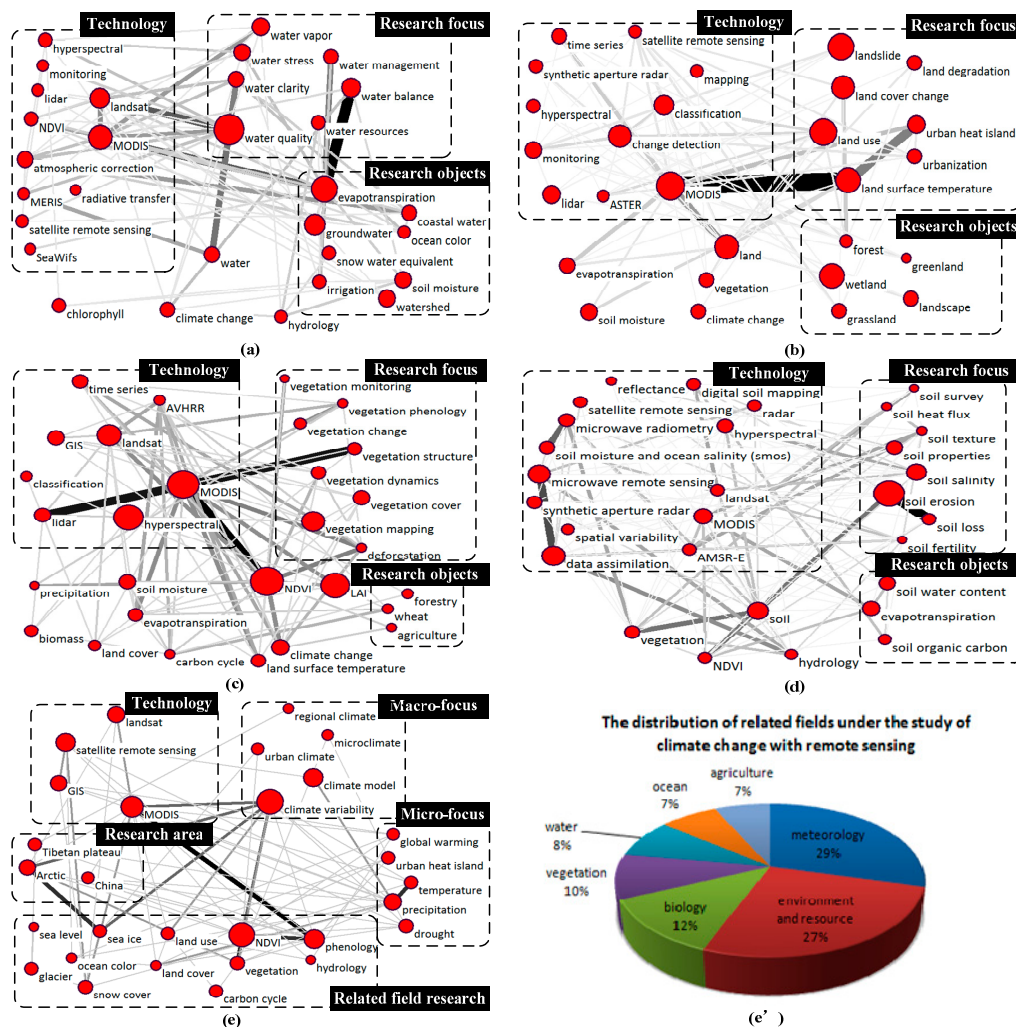
4.3. Remote Sensing Applications

Remote sensing technologies and methodologies have been applied in a wide range of fields, promoting the further rapid development of remote sensing applications [48,49]. In the early years, remote sensing applications were under-developed, with a limited number of applications, including water, vegetation, land, and soil (Figure 4). However, during the 2003–2007 period, the scope of remote sensing applications expanded rapidly, partially attributed to rapid technology development. Climate, energy, and the atmosphere appeared as emerging fields within the application category with an increased frequency of publications. Meanwhile, additional keywords were added to each sub-category of applications, indicating the increasing richness of research themes. Since 2008, remote sensing applications have received increased attention in two emerging fields (i.e., agriculture and natural hazards), while the keywords within each sub-category remain nearly unchanged except for climate. A new hotspot in the climate sub-category is "land surface temperature", which is related to global warming. The shift in keywords reflects the changing tendencies of climate research. During the fourth stage (2013–2021), the number of publications in the categories of climate, vegetation, and land was expected to increase continuously. In addition, urbanization became an emerging research focus within the category of applications [50]. Urbanization is expected to be an increasing concern in the near future.

Furthermore, the overall tendencies of the main categories have varied over time (Figure 5). Among the nine categories considered, land and vegetation have the most publications (14,838 and 12,975, respectively) during the past 19 years, indicating that these two areas were dominant research themes within remote sensing applications (Figure 5). Soil, as the third main field, was the focus of a large number of publications prior to 2013. However, the attention on soil-related research began to decrease with lower growth of publications in recent years. In contrast, although climate did not attract much attention in the early years, climate-related research was extensively published after 2008 [51]. The growth in climate remote-sensing-related publications has exceeded that of the other categories, indicating that climate is projected to remain a hot topic in the remote sensing applications. Following climate, the publication numbers on other applications (e.g., atmosphere, agriculture, natural hazards, and urbanization) has shown fairly stable growth. In addition, differences in research foci were analyzed among productive countries. The U.S. was the leading country in many fields, including water, land, vegetation, climate, soil, energy, and atmosphere. In particular, the number of atmosphere-related publications significantly exceeds that of other countries. Following the U.S., China focused more on the land category, attributed to the availability of LANDSAT data. Other productive European countries (i.e., Germany, the UK, and France) have similar research tendencies in remote sensing applications as the U.S., although these countries have fewer publications than the U.S. and China.

4.3.1. Water and Hydrology

Water was one of the earliest applications of remote sensing due to its close relationship with multiple research fields, such as the environment, resources, and climate [52]. In the early years, insufficient data, lower resolutions, and cost considerations represented significant challenges to the successful development of water-related remote sensing [53]. As a result, since 2003, researchers have begun to seek more advanced technologies or methodologies to expand the research scope. Our analysis also indicated an increasing number of water-related publications (Figure 5). Moreover, the research focus of water remote sensing has transformed from monitoring the sea ice in the early years towards more sustainable and complex issues, such as water quality, water balance, water vapor, and water stress (Figure 6). Furthermore, evapotranspiration and groundwater remain major research objectives, with support from MODIS and LANDSAT data. Timely remote sensing data may drive a new research direction in the area of water reflectance, which could be applied in hydrological forecasting, natural hazards, and climate change.

Figure 6. The interconnection network of remote sensing application categories: (**a**) represents the interconnection network of water remote sensing; (**b**) represents the interconnection network of land remote sensing; (**c**) represents the interconnection network of vegetation remote sensing; (**d**) represents the interconnection network of soil remote sensing; (**e**) represents the interconnection network of climate remote sensing; (**e'**) represents the distribution of related fields under the category of climate remote sensing.

4.3.2. Land-Use and Land-Cover Change

Land-use and land-cover change (LUCC) within terrestrial ecosystems has become a focus of global research in recent decades [54]. LUCC-related publications have been dramatically increasing since 2007, similar to increases in water remote sensing research publications (Figure 5). A number of studies have been conducted to examine LUCC with a focus on ecosystems that are supported by remote sensing technology at regional or national scale [55–57]. Among the five common LUCC-related ecosystems (i.e., agriculture, forest, grassland, water, and built-up land), wetland (7655) and grassland (4487) have been studied the most as shown by the interconnection network of keywords (Figure 6). Moreover, with the development of remote sensing technology, more accurate and timely land-use category conversion data would be used to investigate human disturbance on the environment. For example, global LUCC products are available from AVHRR, MODIS, and MERIS sensor data based on the development and application of technologies, such as Change Vector Analysis (CVA), Principle Component Analysis (PCA), and Artificial Neural Networks (ANNs) [58]. With the requirement of high resolution, urban research has become an emerging hotspot, mainly involving urbanization and urban heat island effects.

4.3.3. Vegetation and Deforestation

Vegetation constitutes a source of energy, construction material, livestock fodder, and medicine. Vegetation serves a number of important ecosystem functions, including atmospheric carbon sequestration, soil erosion control, and groundwater recharge [59–62]. Our analysis shows that vegetation has been widely studied from various perspectives, mainly including vegetation mapping, vegetation cover, vegetation dynamics, and vegetation structure (Figure 6). To further identify the research emphasis in the vegetation category, keywords and titles of 12,726 articles related to the vegetation subject were screened. As a result, 7887 articles focusing on the change in vegetation cover or change geographically and 4783 articles on the abundance of species and diversity were identified. However, only 2343 articles addressed environmental-related issues, such as deforestation. This finding indicates that research related to interactions between vegetation and the environment has been relatively low. In addition, following MODIS, it is worth noting that hyperspectral data provide strong support for vegetation remote sensing research. The combination of hyperspectral and MODIS has become the main data source for vegetation remote sensing.

4.3.4. Soil Moisture and Evapotranspiration

Soil moisture remote sensing has long been regarded as a key variable for understanding global climate and weather systems due to its strong impact on hydro-meteorological processes within the atmospheric boundary layer [63]. Although soil moisture remote-sensing-related publications were growing slowly from 1999 to 2007, the publication rate has increased rapidly since 2008. To develop a holistic understanding of global soil moisture research, a range of different observational scales of soil moisture were adopted (Figure 6). For instance, the Soil Moisture and Ocean Salinity (SMOS) and Soil Moisture Active Passive (SMAP) missions were launched in 2009 and 2012, respectively, which aim to provide soil moisture mapping and estimation at suitable spatial and temporal resolutions for a range of scientific disciplines [64,65]. Microwave remote sensing methods are extensively employed in soil moisture observation using SMAP/GNSS satellites [66]. With the development of related technologies, it provides support to monitor soil moisture/carbon content research more effectively. These datasets assist in understanding a series of soil related research fields, such as soil erosion, soil salinity, and soil properties.

4.3.5. Climate Variability/Change

Continuous monitoring of climate systems plays a vital role in providing timely observational data, which is critical for understanding climate change variability and change [67]. Satellite and MODIS data contribute significantly to the improvement of meteorological reanalysis products that are widely used for climate extremes and climate change research,

e.g., the National Center for Environmental Prediction (NCEP) [68]. The increasing number of climate-related publications indicates that climate remote sensing has been increasing rapidly in recent years (Figure 5). Our analysis indicates that climate variability, climate models, and regional climate were frequently hot points at the macro-focus level. In particular, research on urban climate (e.g., urban heat island) and regional climate (e.g., Arctic, Tibetan Plateau, and China) provides improved understanding of these systems. In addition, climate remote sensing has been applied to a wide range of fields. For example, 29% of climate-change-related publications focused on meteorology, and 27% of these were in the field of environment and resources. Almost 12% of climate change publications are related to biological topics, while other related publications made up the remaining 10% of climate change related publications, such as vegetation, agriculture, water, and the ocean (Figure 6). This suggests that climate variability/change related research has been markedly driven in part by remote sensing, and it has more cross-over studies with other related topics.

4.3.6. Other Fields

An increasing number of hot fields has emerged by integrating conventional remote sensing methodologies with modern technologies, such as urbanization, transport, and even military applications. For example, Garouani (2017) reported that the publication on urban growth with remote sensing already accounted for 10% of urbanization-related publications in 2021 [69]. Studies on urbanization with remote sensing have been increasingly reported to enhance the quantification and understanding of urban growth and urban development patterns. Similarly, applications on transport with ground remote sensing monitoring systems greatly expand the monitoring scale and provide timely information to facilitate improved transport planning, such as road network structure, parking size, and traffic demand [70]. This finding suggests that the development of remote sensing may stimulate interdisciplinary research and applications.

5. Conclusions

This study evaluated a total of 28,437 remote-sensing-related publications from 1999 to 2021 using a bibliometric analysis. This analysis reveals that publications on remote sensing have become more extensive and global over the past 19 years. We performed the interconnection network and evolution of keywords to identify research hotspots as well as the trends in remote sensing technology, methodology, and application at different stages. Moreover, the nexus among the three categories was further analyzed, which reveals the processes of promoting research changes in recent years. The discussion of global collaboration, characterization of research areas, and journal performance provide a valuable reference for researchers and decision makers in the fields of remote sensing.

One significant challenge for field applications of remote sensing is a lack of data. However, this issue was not well represented in analysis of publications on remote sensing applications. Therefore, future efforts should concentrate on retrieving data from multiple sources to provide more comprehensive information. However, previous studies conducted with multi-source remote sensing data were still unable to fully represent the complex nature or society conditions. For example, although multi-source remote sensing data have been used, the contribution of each dataset has not been disaggregated following a coherent framework. Furthermore, the complexity and customization of remote sensing applications may place high demands on the characteristics of multi-source remote sensing data. These requirements highlight the importance of establishing long-term multi-source datasets, including not only remote sensing data but also potential data sources, such as unmanned aerial vehicle data, ground observation data, and even empirical data in future research.

Global remote sensing applications, especially in the environmental field, are gradually transitioning from environmental monitoring to environmental regionalization, environmental impact assessment, and prediction research. For example, the appearance of "water quality", "water management", and "groundwater remediation" among key words from

water remote sensing research promote this transition towards increased environmental focus. Therefore, the diagnostic assessment of environmental conditions and the development of real-time monitoring systems provide useful information for practitioners and researchers to predict future changes and evaluate the performance of ongoing applications. However, less than 20% of the publications are related to prediction studies, which suggest the need for research on prediction to promote environmental management.

With more data, the scale of remote sensing applications has expanded, and there is growing demand for cross-regional collaborative research. However, remote sensing topics (e.g., land-use and land-cover change (LUCC), soil moisture, evapotranspiration, and deforestation) were mostly evaluated separately in previous studies according to our analysis. The interaction and integration among different sub-natural systems should also be taken into consideration as an integral part of remote sensing application plans. According to our analysis, climate change has become a research hotspot since 2003 with a rapid growth rate. The comprehensive consideration of various aspects, such as sea-level rise, snow and ice solar radiation, water vapor, and aerosols helps to better understand the impact of climate change on various natural systems. In addition, the sharing of remote sensing data would allow more studies on cross-regional or even global research.

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References

1. Overpeck, J.T.; Meehl, G.A.; Bony, S.; Easterling, D.R. Climate data challenges in the 21st century. *Science* **2011**, *331*, 700–702. [CrossRef] [PubMed]
2. Benz, U.C.; Hofmann, P.; Willhauck, G.; Lingenfelder, I.; Heynen, M. Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. *ISPRS J. Photogramm. Remote Sens.* **2004**, *58*, 239–258. [CrossRef]
3. Xu, L.L.; Herold, M.; Tsendbazar, N.E.; Masiliunas, D.; Li, L.L.; Lesiv, M.; Fritz, S.; Verbesselt, J. Time series analysis for global land cover change monitoring: A comparison across sensors. *Remote Sens. Environ.* **2022**, *271*, 112905. [CrossRef]
4. Yang, J.; Gong, P.; Fu, R.; Zhang, M.H.; Chen, J.M.; Liang, S.L.; Xu, B.; Shi, J.C.; Dickinson, R. The role of satellite remote sensing in climate change studies. *Nat. Clim. Change* **2013**, *3*, 875–883. [CrossRef]
5. Kollias, P.; Battaglia, A.; Tatarevic, A.; Lamer, K.; Tridon, F.; Pfitzenmaier, L. EarthCARE Cloud Profiling Radar (CPR) Doppler measurements in deep convection: Challenges, post-processing and science applications. *Remote Sens. Atmos. Clouds Precip. VII* **2018**, *10776*, 57–68. [CrossRef]
6. Iguchi, T.; Kanemaru, K.; Hamada, A. Possible Improvement of the GPM's Dual-frequency Precipitation Radar (DPR) Algorithm. *Remote Sens. Atmos. Clouds Precip. VII* **2018**, *10776*, 51–56. [CrossRef]
7. Zahiri, E.P.; Kacou, M.; Gosset, M.; Ouattara, S.A. Modeling the Interdependence Structure between Rain and Radar Variables Using Copulas: Applications to Heavy Rainfall Estimation by Weather Radar. *Atmosphere* **2022**, *13*, 1298. [CrossRef]
8. Zhang, B.; Li, X.F.; Perrie, W.; He, Y.J. Synergistic measurements of ocean winds and waves from SAR. *J. Geophys. Res.-Ocean.* **2015**, *120*, 6164–6184. [CrossRef]
9. Zhuang, H.F.; Fan, H.D.; Deng, K.Z.; Yu, Y. An improved neighborhood-based ratio approach for change detection in SAR images. *Eur. J. Remote Sens.* **2018**, *51*, 723–738. [CrossRef]

10. Bayindir, C.; Frost, J.D.; Barnes, C.F. Assessment and Enhancement of SAR Noncoherent Change Detection of Sea-Surface Oil Spills. *IEEE J. Ocean. Eng.* **2018**, *43*, 211–220. [CrossRef]

11. Liu, Y.; Sarnat, J.A.; Kilaru, V.; Jacob, D.J.; Koutrakis, P. Estimating ground-level PM2.5 in the eastern United States using satellite remote sensing. *Environ. Sci. Technol.* **2005**, *39*, 3269–3278. [CrossRef]

12. Gong, P.; Wang, J.; Yu, L.; Zhao, Y.; Zhao, Y.; Liang, L.; Niu, Z.; Huang, X.; Fu, H.; Liu, S.; et al. Finer resolution observation and monitoring of global land cover: Frst mapping results with Landsat TM and ETM+ data. *Int. J. Remote Sens.* **2013**, *34*, 2607–2654. [CrossRef]

13. Penner, J.E.; Xu, L.; Wang, M. Satellite methods underestimate indirect climate forcing by aerosols. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 13404–13408. [CrossRef]

14. Grifoni, R.C.; Caprari, G.; Marchesani, G.E. Combinative Study of Urban Heat Island in Ascoli Piceno City with Remote Sensing and CFD Simulation-Climate Change and Urban Health Resilience-CCUHRE Project. *Sustainability* **2022**, *14*, 688. [CrossRef]

15. Lund, M.; Raundrup, K.; Westergaard-Nielsen, A.; López-Blanco, E.; Nymand, J.; Aastrup, P. Larval outbreaks in West Greenland: Instant and subsequent effects on tundra ecosystem productivity and CO2 exchange. *Ambio* **2017**, *46*, 26–38. [CrossRef]

16. Donlon, C.; Berruti, B.; Buongiorno, A.; Ferreira, M.H.; Femenias, P.; Frerick, J.; Goryl, P.; Klein, U.; Laur, H.; Mavrocordatos, C.; et al. The Global Monitoring for Environment and Security (GMES) Sentinel-3 mission. *Remote Sens. Environ.* **2012**, *120*, 37–57. [CrossRef]

17. Wikantika, K.; Ghazali, M.F.; Dwivany, F.M.; Novianti, C.; Yayusman, L.F.; Sutanto, A. Integrated Studies of Banana on Remote Sensing, Biogeography, and Biodiversity: An Indonesian Perspective. *Diversity* **2022**, *14*, 277. [CrossRef]

18. Atzberger, C. Advances in Remote Sensing of Agriculture: Context Description, Existing Operational Monitoring Systems and Major Information Needs. *Remote Sens.* **2013**, *5*, 949–981. [CrossRef]

19. Agutu, N.O.; Awange, J.L.; Zerihun, A.; Ndehedehe, C.E.; Kuhn, M.; Fukuda, Y. Assessing Multi-satellite Remote Sensing, Reanalysis, and Land Surface Models' Products in Characterizing Agricultural Drought in East Africa. *Remote Sens. Environ.* **2017**, *194*, 287–302. [CrossRef]

20. Poursanidis, D.; Chrysoulakis, N. Remote Sensing, natural hazards and the contribution of ESA Sentinels missions. *Remote Sens. Appl. Soc. Environ.* **2017**, *6*, 25–38. [CrossRef]

21. Zhuang, Y.H.; Liu, X.J.; Nguyen, T.; He, Q.Q.; Hong, S. Global remote sensing research trends during 1991–2010: A bibliometric analysis. *Scientometrics* **2013**, *96*, 203–219. [CrossRef]

22. Pritchard, A. Statistical Bibliography or Bibliometrics? *J. Doc.* **1969**, *25*, 348–349.

23. Wang, M.H.; Li, J.F.; Ho, Y.S. Research articles published in water resources journals: A bibliometric analysis. *Desalination Water Treat.* **2011**, *28*, 353–365. [CrossRef]

24. Donthu, N.; Kumar, S.; Mukherjee, D.; Pandey, N.; Lim, W.M. How to conduct a bibliometric analysis: An overview and guidelines. *J. Bus. Res.* **2021**, *133*, 285–296. [CrossRef]

25. Garfield, E. The history and meaning of the journal impact factor. *JAMA-J. Am. Med. Assoc.* **2006**, *295*, 90–93. [CrossRef]

26. Mao, G.Z.; Liu, X.; Du, H.B.; Zuo, J.; Wang, L.Y. Way forward for alternative energy research: A bibliometric analysis during 1994–2013. *Renew. Sustain. Energy Rev.* **2015**, *48*, 276–286. [CrossRef]

27. Gao, M.; Hong, F.; Liu, J. Investigation on energy storage and quick load change control of subcritical circulating fluidized bed boiler units. *Appl. Energy* **2017**, *185*, 463–471. [CrossRef]

28. Han, M.Y.; Sui, X.; Huang, Z.L.; Wu, X.D.; Xia, X.H.; Hayat, T.; Alsaedi, A. Bibliometric indicators for sustainable hydropower development. *Ecol. Indic.* **2014**, *47*, 231–238. [CrossRef]

29. Zheng, T.L.; Wang, J.; Wang, Q.H.; Nie, C.H.; Shi, Z.N.; Wang, X.N.; Gao, Z. A bibliometric analysis of micro/nano-bubble related research: Current trends, present application, and future prospects. *Scientometrics* **2016**, *109*, 53–71. [CrossRef]

30. Mclinden, D. Concept maps as network data: Analysis of a concept map using the methods of social network analysis. *Eval. Program Plan.* **2013**, *36*, 40–48. [CrossRef]

31. Ozyar, E.; Gurdalli, S. Social network analysis: A powerful strategy, also for the information sciences. *J. Inf. Sci.* **2002**, *28*, 441–453. [CrossRef]

32. Xu, X.; Taylor, J.E.; Pisello, A.L.; Culligan, P.J. The impact of place-based affiliation networks on energy conservation: An holistic model that integrates the influence of buildings, residents and the neighborhood context. *Energy Build.* **2012**, *55*, 637–646. [CrossRef]

33. Sankar, C.P.; Asokan, K.; Kumar, K.S. Exploratory social network analysis of affiliation networks of Indian listed companies. *Soc. Netw.* **2015**, *43*, 113–120. [CrossRef]

34. Saldanha, I.J.; Li, T.; Yang, C.; Ugarte-Gil, C.; Rutherford, G.W.; Dickersin, K. Social network analysis identified central outcomes for core outcome sets using systematic reviews of HIV/AIDS. *J. Clin. Epidemiol.* **2016**, *70*, 164–175. [CrossRef]

35. Makagon, M.M.; Mccowan, B.; Mench, J.A. How can social network analysis contribute to social behavior research in applied ethology? *Appl. Anim. Behav. Sci.* **2012**, *138*, 152–161. [CrossRef]

36. Leydesdorff, L.; Vaughan, L. Co-occurrence matrices and their applications in information science: Extending ACA to the Web environment. *J. Am. Soc. Inf. Sci. Technol.* **2006**, *57*, 1616–1628. [CrossRef]

37. Yang, W. Policy: Boost basic research in China. *Nature* **2016**, *534*, 467–469. [CrossRef]

38. Bozeman, B.; Fay, D.; Slade, C.P. Research collaboration in universities and academic entrepreneurship: The-state-of-the-art. *J. Technol. Transf.* **2013**, *38*, 1–67. [CrossRef]

39. Shu, Z.; Mao, G.; Crittenden, J.; Liu, X.; Du, H.B. Groundwater remediation from the past to the future: A bibliometric analysis. *Water Res.* **2017**, *119*, 114–125. [CrossRef]

40. Li, J.; Wang, M.H.; Ho, Y.S. Trends in research on global climate change: A Science Citation Index Expanded-based analysis. *Glob. Planet. Change* **2011**, *77*, 13–20. [CrossRef]

41. Yun, F.; Zheng, J. An Analysis of Status and Trends of the International Remote Sensing Science on Bibliometrics. *Remote Sens. Technol. Appl.* **2005**, *20*, 526–530. [CrossRef]

42. Soubry, I.; Doan, T.; Chu, T.; Guo, X.L. A Systematic Review on the Integration of Remote Sensing and GIS to Forest and Grassland Ecosystem Health Attributes, Indicators, and Measures. *Remote Sens.* **2021**, *13*, 3262. [CrossRef]

43. Petropoulos, G.P.; Arvanitis, K.; Sigrimis, N. Hyperion hyperspectral imagery analysis combined with machine learning classifiers for land use/cover mapping. *Expert Syst. Appl.* **2012**, *39*, 3800–3809. [CrossRef]

44. Rulinda, C.M.; Dilo, A.; Bijker, W.; Stein, A. Characterising and quantifying vegetative drought in East Africa using fuzzy modelling and NDVI data. *J. Arid Environ.* **2012**, *78*, 169–178. [CrossRef]

45. Gitelson, A.; Garbuzov, G.; Sailagyi, F.; Mittenzwey, K.H.; Karnieli, A.; Kaiser, A. Quantitative remote sensing methods for real-time monitoring of inland waters quality. *Int. J. Remote Sens.* **1993**, *14*, 1269–1295. [CrossRef]

46. Sever, T.L. Remote Sensing Methods. *Hydrol. Sci. J.* **2000**, *43*, 509. [CrossRef]

47. Stubbs, J.H.; Mckee, K.L.R. Applications of Remote Sensing to the Understanding and Management of Cultural Heritage Sites. *Interdiscip. Contrib. Archaeol.* **2006**, *54*, 515–540. [CrossRef]

48. Blaschke, T. Object based image analysis for remote sensing. *ISPRS J. Photogramm. Remote Sens.* **2010**, *65*, 2–16. [CrossRef]

49. Li, J.X.; Hong, D.F.; Gao, L.R.; Yao, J.; Zheng, K.; Zhang, B.; Chanussot, J. Deep learning in multimodal remote sensing data fusion: A comprehensive review. *Int. J. Appl. Earth Obs. Geoinf.* **2022**, *122*, 102926. [CrossRef]

50. Xu, H.; Wang, X.; Xiao, G. A remote sensing and GIS integrated study on urbanization with its impact on arable lands: Fuqing City, Fujian Province, China. *Land Degrad. Dev.* **2015**, *11*, 301–314. [CrossRef]

51. Weng, Q. Thermal infrared remote sensing for urban climate and environmental studies: Methods, applications, and trends. *Isprs J. Photogramm. Remote Sens.* **2009**, *64*, 335–344. [CrossRef]

52. Ji, D.; Shi, J.; Xiong, C.; Wang, T.; Zhang, Y. A total precipitable water retrieval method over land using the combination of passive microwave and optical remote sensing. *Remote Sens. Environ.* **2017**, *191*, 313–327. [CrossRef]

53. Rostom, N.G.; Shalaby, A.A.; Issa, Y.M.; Afifi, A.A. Evaluation of Mariut Lake water quality using Hyperspectral Remote Sensing and laboratory works. *Egypt. J. Remote Sens. Space Sci.* **2017**, *20*, 39–48. [CrossRef]

54. Houghton, R.A. Magnitude, distribution and causes of terrestrial carbon sinks and some implications for policy. *Clim. Policy* **2002**, *2*, 71–88. [CrossRef]

55. Shevliakova, E.; Pacala, S.W.; Malyshev, S.; Crevoisier, C. Carbon cycling under 300 years of land use change: Importance of the secondary vegetation sink. *Glob. Biogeochem. Cycles* **2009**, *23*, 91–100. [CrossRef]

56. Chen, X.; Zhang, Y. Impacts of urban surface characteristics on spatiotemporal pattern of land surface temperature in Kunming of China. *Sustain. Cities Soc.* **2017**, *32*, 87–99. [CrossRef]

57. Zhang, J.; Li, X.C.; Zhang, C.C.; Yu, L.; Wang, J.Z.; Wu, X.Y.; Hu, Z.W.; Zhai, Z.H.; Li, Q.Q.; Wu, G.F.; et al. Assessing spatiotemporal variations and predicting changes in ecosystem service values in the Guangdong-Hong Kong-Macao Greater Bay Area. *Gisci. Remote Sens.* **2022**, *59*, 184–199. [CrossRef]

58. Small, C.; Sousa, D. Humans on Earth: Global extents of anthropogenic land cover from remote sensing. *Anthropocene* **2016**, *14*, 1–33. [CrossRef]

59. Bailis, R.; Ezzati, M.; Kammen, D.M. Mortality and greenhouse gas impacts of biomass and petroleum energy futures in Africa. *Science* **2005**, *308*, 98–103. [CrossRef]

60. Breed, M.F.; Ottewell, K.M.; Gardner, M.G.; Lowe, A.J. Clarifying climate change adaptation responses for scattered trees in modified landscapes. *J. Appl. Ecol.* **2011**, *48*, 637–641. [CrossRef]

61. Saatchi, S.S.; Harris, N.L.; Brown, S.; Lefsky, M.; Mitchard, E.T.A.; Salas, W.; Zutta, B.R.; Buermann, W.; Lewis, S.L.; Hagen, S.; et al. Benchmark map of forest carbon stocks in tropical regions across three continents. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 9899–9904. [CrossRef] [PubMed]

62. Zhang, X.; Zhang, L.X.; Wang, Y.X.; Shao, Y.; Daniels, B.; Ross-Nickoll, M.; Chen, Z.L. Pollinators and urban riparian vegetation: Important contributors to urban diversity conservation. *Environ. Sci. Eur.* **2022**, *34*, 78. [CrossRef]

63. Mao, T.N.; Shangguan, W.; Li, Q.L.; Li, L.; Zhang, Y.; Huang, F.N.; Li, J.D.; Liu, W.; Zhang, R.Q. A Spatial Downscaling Method for Remote Sensing Soil Moisture Based on Random Forest Considering Soil Moisture Memory and Mass Conservation. *Remote Sens.* **2022**, *14*, 3858. [CrossRef]

64. Zhao, W.; Li, Z.L. Sensitivity study of soil moisture on the temporal evolution of surface temperature over bare surfaces. *Int. J. Remote Sens.* **2013**, *34*, 3314–3331. [CrossRef]

65. Al-Yaari, A.; Wigneron, J.P.; Ducharne, A.; Kerr, Y.H.; Wagner, W.; Lannoy, G.D.; Reichle, R.; Bitar, A.A.; Dorigo, W.; Richaume, P.; et al. Global-scale comparison of passive (SMOS) and active (ASCAT) satellite based microwave soil moisture retrievals with soil moisture simulations (MERRA-Land). *Remote Sens. Environ.* **2014**, *152*, 614–626. [CrossRef]

66. Wagner, W.; Naeimi, V.; Scipal, K.; De Jeu, R.; Martinez-Fernandez, J. Soil moisture from operational meteorological satellites. *Hydrogeol. J.* **2007**, *15*, 121–131. [CrossRef]

67. Ayanu, Y.Z.; Conrad, C.; Nauss, T.; Wegmann, M.; Koellner, T. Quantifying and Mapping Ecosystem Services Supplies and Demands: A Review of Remote Sensing Applications. *Environ. Sci. Technol.* **2012**, *46*, 8529–8541. [CrossRef]
68. Chen, M.; Zhuang, Q.L.; He, Y.J. An Efficient Method of Estimating Downward Solar Radiation Based on the MODIS Observations for the Use of Land Surface Modeling. *Remote Sens.* **2014**, *6*, 7136–7157. [CrossRef]
69. Garouani, A.E.; Mulla, D.J.; Garouani, S.E.; Knight, J. Analysis of urban growth and sprawl from remote sensing data: Case of Fez, Morocco. *Int. J. Sustain. Built Environ.* **2017**, *6*, 160–169. [CrossRef]
70. Yu, X.; Shi, Z. Vehicle detection in remote sensing imagery based on salient information and local shape feature. *Optik* **2015**, *126*, 2485–2490. [CrossRef]