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Earth Observation Systems and Pasture Modeling: A Bibliometric Trend Analysis

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Abstract: An Earth observation system (EOS) is essential in monitoring and improving our understanding of how natural and managed agricultural landscapes change over time or respond to climate change and overgrazing. Such changes can be quantified using a pasture model (PM), a critical tool for monitoring changes in pastures driven by the growing population demands and climate change-related challenges and thus ensuring a sustainable food production system. This study used the bibliometric method to assess global scientific research trends in EOS and PM studies from 1979 to 2019. This study analyzed 399 published articles from the Scopus indexed database with the search term "Earth observation systems OR pasture model". The annual growth rate of 19.76% suggests that the global research on EOS and PM has increased over time during the survey period. The average growth per article is n = 74, average total citations (ATC) = 2949 in the USA, is n = 37, ATC = 488, in China and is n = 22, ATC = 544 in Italy). These results show that the field of the study was inconsistent in terms of ATC per article during the study period. Furthermore, these results show three countries (USA, China, and Italy) ranked as the most productive countries by article publications and the Netherlands had the highest average total citations. This may suggest that these countries have strengthened research development on EOS and PM studies. However, developing counties such as Mexico, Thailand, Sri Lanka, and other African countries had a lower number of publications during the study period. Moreover, the results showed that Earth observation is fundamental in understanding PM dynamics to design targeted interventions and ensure food security. In general, the paper highlights various advances in EOS and PM studies and suggests the direction of future studies.

Keywords: bibliometrics; climate change; EOS; PM; remote sensing

1. Introduction

Pastures are one of the most widespread terrestrial plant systems [1]. Pastures cover about 31.5% of the global land area and other land cover types such as farmland and managed grazing lands, thus making pastures predominant among nature's services [1,2]. Pastures are the second largest coverage of the Earth's surface and are also second in carbon dioxide sequestration from the atmosphere after forests [2–4]. Pastures are an important natural resource that supports plant growth and provide a cheap feed source for livestock production [5]. Consequently, the functions and benefits of pastures are associated with soil erosion protection, nutrient persistence, and are a habitat for animal biodiversity, among others [6,7]. Global studies suggested different trends in pastures dynamics [8–10]. Such studies estimate 40% of pasture degradation globally between 1982 and 2006 [11,12]. In Europe, pastures have undergone reductions in quality and quantity through the intensification of animal production over the past decades [13]. Eastern Spain, western Mediterranean Badlands, Loess Plateau of China, eastern Himalayas of India, Western Brazilian Amazon, and Slovakia have been affected by high soil erosion rates leading to the degradation of pastures and rangeland ecosystems [14–16]. Large areas in Australia, South America, India, and half of the pasture surface in Africa have experienced varying degrees of deterioration from grazing pressure and soil erosion [5,17–19]. Meanwhile, pastures suffer from poor farming methods and long-term grazing and unsustainable stocking levels in sub-Saharan Africa [20,21]. In southern Africa, pastures have been over-utilized for livestock production and are often associated with intensive agricultural production systems [22]. Consequently, the increasing rate of overgrazing is one of the leading factors in the degradation of pastures globally [13,20]. Therefore, continuous monitoring of pastures is crucial to track changes in grazing capacity and intensity in any given region.

Studies show that pastures are affected by different factors such as climate change, overgrazing, soil erosion, urbanization, mining, and land-use change [23–25]. These factors present multiple threats to livestock production, human society, vegetated ecosystem, and natural resource conservation [5,24,26]. Climate change projections indicate that pastures will experience extreme water shortage, heat stress, and prolonged growing seasons [27]. Global climate models (GCM) have predicted that the temperature is expected to increase from 1 to 1.25 °C and may impede pasture growth across regions. Consequently, areas with rainfall deficits could experience a reduction in pasture productivity [28]. Weather parameters such as temperature and rainfall have significantly influenced pasture dynamics over the past decades [29]. Many studies have reported that overgrazing has threatened native vegetation and reduced soil infiltration thereby inhibiting pasture growth [8,30]. Soil erosion is one of the factors that reduces soil fertility, which facilitates pasture growth and development [16]. The expansion of built-up areas leads to the total loss of pasture areas [31]. A study reported that pollution from industrial, mining, and agricultural activities poses a significant impact on pasture conditions [32]. Meanwhile, intensive land-use change can also improve or degrade pasture areas [33]. Therefore, it is important to explore the existing literature and identify other influential factors that can contribute to pasture loss or degradation in a given region. On the other hand, pasture modeling based on the experimentation of monitoring the condition is short-lived and expensive. The breakthrough of Earth observation systems to monitor the Earth's surface provides optimal, timely, and cost-effective techniques for pasture modeling on large scales. Pasture model (PM) refers to an incremental change in time to monitor and assess pasture conditions in response to climate, urbanization, soil evaporation, overgrazing, runoff, and land-use change [34,35]. In general, pastures are monitored with the aid of conventional and remotely sensed techniques. Conventional techniques are used to determine pasture quality and require detailed sampling. However, this presents limited information about the spatial pattern of pasture dynamics. Limitations of conventional methods also include the high cost of laboratory analysis and are prone to human errors [36,37]. Remote sensing techniques are superior to conventional methods; they provided robust and time-effective solutions. The demonstration of the use of acquired remote sensing data and its suitability in monitoring grazing lands cannot be overemphasized with different use of satellite multi-sensors. Notable limitations of satellite remote sensing techniques are associated with big data assimilation in managing spectral and spatial resolutions over time. However, current advances in cloud computing and the launch of improved satellite sensors address these limitations. For instance, the recent advancements in Earth observation systems such as synthetic aperture radar (SAR) Sentinel-1 and optical imagery of Sentinel-2 are associated with improved spectral and spatial resolutions to monitor pasture change dynamics [38,39]. Remote sensing data have been efficiently used to predict pasture yields, herbage quality, productivity, and pasture quality parameters [40,41]. Therefore, it is important to appraise the evolutionary trends and identify current research hotspots to better understand the dominant themes by using the bibliometric method of published literature on EOS and PM studies.

Bibliometrics is a comprehensive statistical method used in evaluating published literature [42–46]. Generally, bibliometric analysis provides a clear understanding of published research articles on informative and objective scientific studies within a specified field of study [47–52]. Most studies used bibliometric analysis to identify gaps and advance the literature review in a specific niche area [53–60]. This study assessed global scientific research history on EOS and PM studies from 1979 to 2019. The study appraised published articles by assessing the annual scientific production, author's global citation, decadal trending topics, keywords co-occurrence network, journal analysis, institutions, and countries' collaboration on EOS and PM studies. The outcome of this study is fundamental in Earth observation systems by providing important information on pasture model dynamics for designing targeted interventions and ensuring food security.

2. Data Collection, Preparation and Methods

The Scopus indexed database provided adequate data to perform a bibliometric analysis on EOS and PM studies and to determine specific trends and identify knowledge gaps. The Scopus database was used to mine the data for this study on 2 October 2020, as presented in Table 1. The bibliometric analysis was carried out using bibliometric R-package (RStudio v4.0), biblioshiny [49,61,62] and VOSviewer software (v1.6.16) [63–65]. The application of these software provides a web interface for bibliometrix [66–69]. These are available open-source software. All publications related to EOS and PM research were searched using the search term ("Earth observation systems OR pasture model"), which include article title, abstract, and keywords from 1979 to 2019. The Boolean operation OR was used to combine the search terms. Therefore, the search terms generated a total of 1102 articles, including conference papers, articles, reviews, book chapters, conference reviews, short surveys, books, editorial, notes, and erratum, from the Scopus database. The search term was refined to 435 articles written in the English language and of review document type. The retrieved 435 articles were processed for data cleaning to identify duplications of articles without authors and affiliations using the Citation Analysis Package (CITAN) in the R repository [49,70]. Data cleaning is one of the basic steps in bibliometric analysis but is time-consuming. CITAN and biblioshiny packages were performed for the disambiguation process of identifying articles without authors and affiliation institutions [70]. Therefore, the study used a total of 399 articles for bibliometric analysis and interpretation. Consequently, the bibliometric method utilized for this study cannot generalize studies on EOS and PM using one database. The analyses were carried out based on published research articles to streamline and focus on published studies that explored EOS and PM to accommodate the niche area. To this end, the highlighted factors shaped the research direction of materials and methods explored and adopted in data collection and analysis. Figure 1 presents the graphical representation of data processing as shown below.

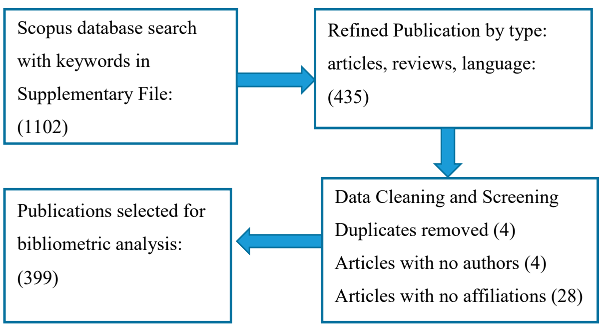

Figure 1. Graphical representation of data processing.

Table 1. Main summary information retrieved on EOS and PM studies (1979–2019).

Description	Results
Time Span	1979–2019
Documents	435
Sources (Journals, Books, etc.)	229
Keywords Plus (ID)	3279
Author's Keywords (DE)	1257
Average Citations per Document	19.76
Authors	1682
Author Appearances	2018
Authors of Multi-Authored Documents	1622
Single-Authored Documents	68
Documents per Author	0.259
Authors per Document	3.78
Co-Authors per Document	4.64
Collaboration Index	4.42
Article	402
Review	33

3. Results

3.1. Characteristics of Scopus Indexed Database

The analysis includes 399 articles published and retrieved from the Scopus database with a focus on EOS and PM during the survey period. Accordingly, Table 1 summarizes the information retrieved from the Scopus database. For example, a collaborative index of 4.42 for 1682 authors have been revealed, with 1622 authors contributing to multi-authored documents and 68 authors of single-authored published documents, as shown in Table 1. The evaluation of journals, books, etc., includes 229 sources with 2018 authors appearances with 0.259 documents per author (3.78 authors per document) and 4.64 co-authors per document. The average annual percentage growth rate was 19.76% of citations per article recorded during the survey period.

3.1.1. Temporal Scientific Contribution per Article

The information in Figure 2 shows a relatively low annual production rate on the number of articles recorded from 1979 to 1993. The notable decreasing trend in articles production rate started in 1980 and continued from 1984, 1990, 1992, 1994, 1997, 1999, 2001, 2006, 2009, 2010, 2013, and 2014, and a steady decrease was observed from 2018 and 2019, respectively. Furthermore, it is worth noting that the trend of publication peaked in some years and significantly decreased in some other years, particularly in 1981, 1990, 1997, and 2014, respectively, while the highest number of publications was observed in 2017. The study observed inconsistency in the publication trend rather than maintaining the same growth rate. During the survey period, an increased average citation per article was observed in 2019, reaching a maximum of 19.76%. Consequently, the average citations per article declined, which connotes that the field of research was unstable in terms of average total citation per document [71].

3.1.2. Scopus Global EOS and PM Most Cited and Spatial Distribution

The information summarized in Table 2 shows the top 20 most cited countries on EOS and PM studies. The number of AAC and published articles varied across EOS and PM studies. However, 61 single-authored articles came from single country publications (SCP), while 13 joint authored articles came from multiple country publications (MCP). The USA ranked first among the top 20 countries based on published articles and total citations during the survey period. The USA accounts for 74 articles in terms of countries' contributions. It is worth noting that, among the most-cited countries, the USA had a total citation accounting for (TC = 2949) and average article citations of (AAC) 39.85, followed by the Netherlands (TC = 1097 and AAC = 219.40) and France (TC = 640 and

AAC = 45.71), respectively. Results show that most of the most cited studies came from developed countries, while a small number of cited studies came from developing countries such as Mexico, Thailand, Sri Lanka, and Brazil, among others. Consequently, there was a low research output from developing countries, which are characterized by a high level of self-funded or autonomous research and a language barrier [72]. The developed country's performance is measured in terms of most article citations, the highest number of publications, and their influence in the field among other developing countries. This implies that the publications of developed countries and the availability of research grants contributed to the increase in research productivity in the EOS and PM studies during the survey period [73,74].

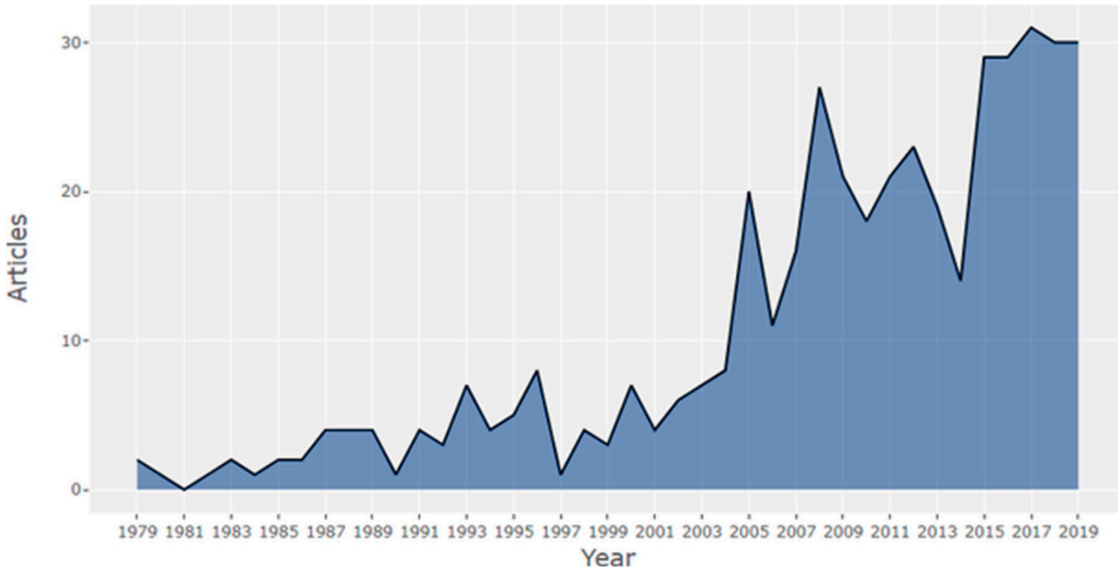

Figure 2. Annual scientific production on EOS and PM from 1979–2019.

3.1.3. Scientific Collaboration Analysis per Countries

Figure 3 shows the top 20 collaborations between countries that contributed to the EOS and PM studies. The bigger the node, the greater the country's dominance per article publication and the number of its associated links between different countries. The most dominant country was the USA, followed by China, France, Italy, Germany, and Japan, respectively. The country's influence in terms of its dominance may suggest the importance of strengthening research needs and collaboration networks to advance EOS and PM studies.

3.1.4. Collaboration Analysis between Institutions

Figure 4 shows the top 20 collaborations between various institutions that contributed to EOS and PM studies. Institutions with larger boxes and thicker connectors represent the strength of dominance in the field per article publication. Wuhan university, followed by the University of Chinese academy of sciences, University of Maryland, Institute of Remote Sensing and Digital Earth in China, California Institute of Technology, and NASA Goddard Spaceflight Center in the USA were amongst the most influential institutions on EOS and PM research. This suggests that scientific collaboration occurs mostly within national borders. The University of Geneva, University of Tokyo, Mississippi State University, Space Research Institute, and University of Defense Technology witnessed little or no publication on EOS and PM studies during the survey period.

Table 2. Top 20 countries most cited per average article citation on EOS and PM from 1979–2019.

Country	Articles	TC	AAC	SCP	MCP	A/MP
USA	74	2949	39.85	61	13	0.176
Netherlands	5	1097	219.40	0	5	1.000
France	14	640	45.71	8	6	0.429
Italy	22	544	24.733	10	12	0.545
China	37	488	12.11	30	7	0.189
Germany	14	281	20.07	10	4	0.286
Brazil	2	192	96.00	1	1	0.500
Switzerland	6	151	25.17	3	3	0.500
Canada	5	149	29.80	3	2	0.400
United Kingdom	5	118	23.60	2	3	0.600
Spain	4	111	27.75	1	3	0.750
Japan	14	83	5.93	11	3	0.214
Austria	2	70	11.67	1	5	0.833
Mexico	2	43	21.50	0	2	1.000
New Zealand	2	41	20.50	2	0	0.000
Greece	3	40	13.33	1	2	0.667
Thailand	1	37	37.00	1	0	0.000
India	8	36	4.50	8	0	0.000
Sri Lanka	1	31	31.00	1	0	0.000
Poland	4	23	5.75	4	0	0.000

Note: Total citations (TC); average article citations (AAC); single country publications (SCP); multiple country publications (MCP); articles per million publications (A/MP).

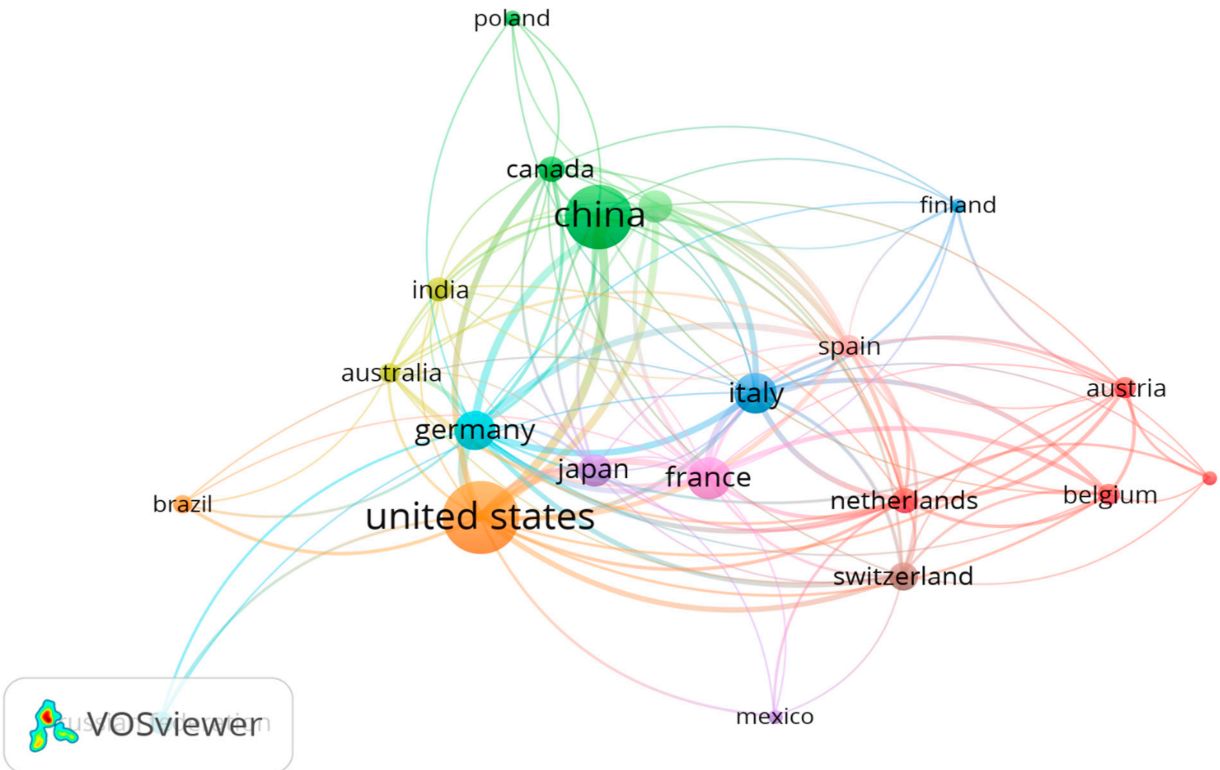

Figure 3. Top 20 Collaboration between Countries Network on EOS and PM Studies.

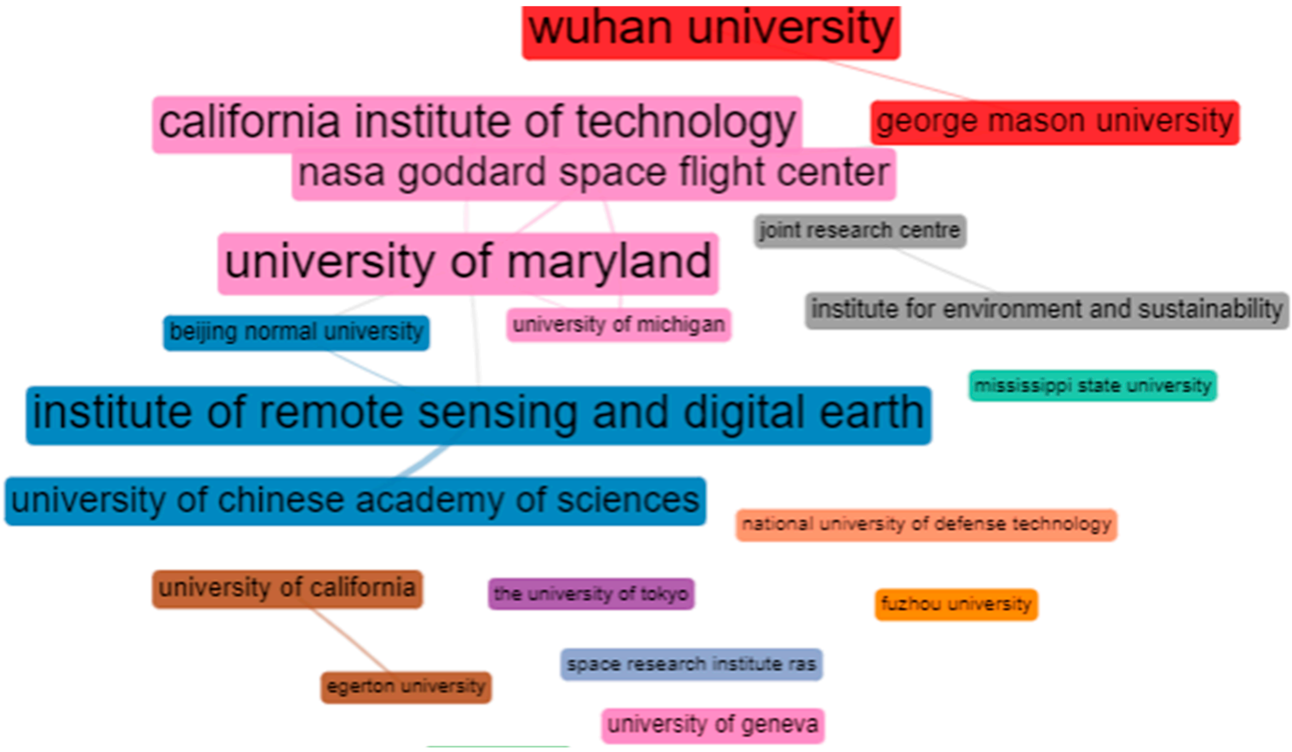

Figure 4. Top 20 Collaboration between institutions network on EOS and PM studies.

3.1.5. Author's Contribution

Figure 5 shows the top 20 global citations of authors' articles in EOS and PM studies. The results show that Drusch M., ranked the most cited author in the field, with the total number of articles accounting for TC = 1030, followed Kaufman Y.J., accounting for TC = 467, and Duchemin B., accounting for TC = 262, respectively. Drusch M. focused on the global monitoring environment, security for the European Commission, and European space agency on EOS and PM studies. Duchemin B., investigated the feasibility of using the normalized difference vegetation index (NDVI) derived from remote sensing data to provide indirect estimates of the leaf area index (LAI), a vital pasture parameter for the crop process model among others. Accordingly, the author's influence in terms of their productivity and the average total citation was centered on EOS and PM studies to measure the author's contribution in a specific field [75].

3.1.6. Journal Analysis

Information in Table 3 shows the top 20 Journals on EOS and PM studies. A total of 229 journals were published on EOS and PM during the survey period. The journal sources were ranked based on the number of most cited articles and each journal start year of publication on EOS and PM studies. IEEE Transaction on Geoscience and Remote Sensing, accounting for (n = 23) in 1987, followed by the Remote Sensing journal accounting for (n = 14) in 1999, and Remote Sensing of Environment accounting for (n = 13) in 2010 had the highest number of articles, with 3.49% of the total. This may suggest that this field is relatively distributed through large journals and covers research erudition across many fields of study [46].

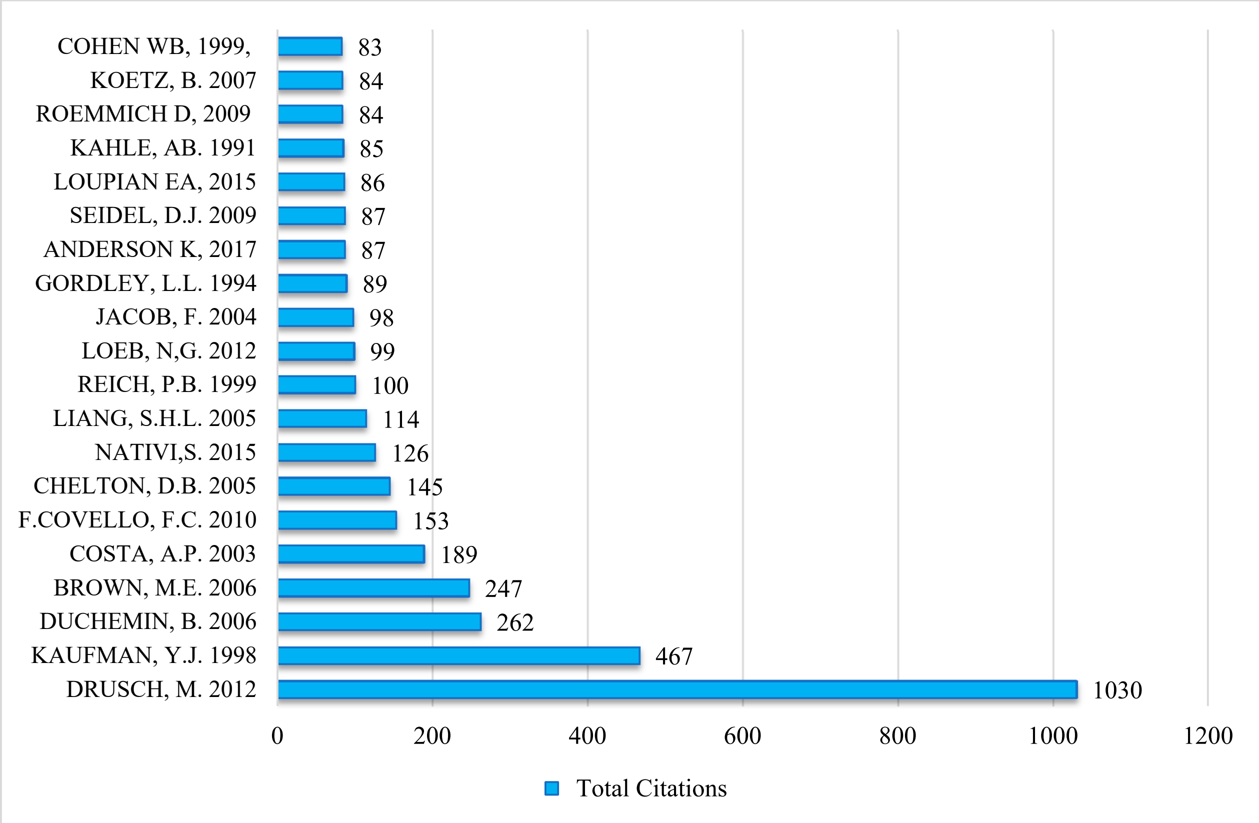

Figure 5. Top 20 global citations of authors on EOS and PM from 1979–2019.

3.1.7. Top Global Cited Published Articles on EOS and PM Studies

The information in Table 4 presents global top-cited articles on EOS and PM studies and summarizes findings explored using different satellites/EOS and models. The studies revealed a synergy between EOS and PM through change detection, satellite type, and algorithms trained and validated for PM. Most studies revealed positive outcomes for pasture models with high-resolution satellites such as Sentinel-2, LIDAR, GF-1, and others [76–78]. Some studies on pasture models showed negative results on EOS such as the Advanced Very High-Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectroradiometer (MODIS). The multisensor data fusion process in EOS may improve the pasture model accuracy, which counters the low-resolution satellite sensors [76,79]. The constant development of Earth observation systems over the years has been inevitable in EOS and PM studies, such that EOS data utilized the normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), and leaf area index (LAI) for calibration and validation of different models [80,81]. Most studies have used remote sensing data, algorithms, and in situ sampling methods to generate data for pasture models [41,82].

Table 3. Top 20 journals on EOS and PM studies from 1979–2019.

Source	NP	TC	Start Year
IEEE Transaction on Geoscience and Remote Sensing.	23	682	1987
Remote Sensing.	14	205	2010
Remote Sensing of Environment.	13	1688	1999
IEEE Journal of Selected Topics in Applied Earth Observation and Remote Sensing.	12	159	2008

Table 3. *Cont.*

Source	NP	TC	Start Year
IEEE Systems Journal.	11	195	2008
Journal of Remote Sensing.	11	93	2016
ACTA Astronautic.	10	106	1987
Advances in Space Research.	10	87	1994
International Journal of Remote Sensing.	8	316	2000
Proceedings of SPIE- the International Society for Optical Engineering.	7	27	1979
Space Policy.	7	120	1995
Computers and Geosciences.	6	176	2005
International Journal of Applied Earth Observation and Geoinformation.	6	139	2009
Canadian Journal of Remote Sensing.	5	103	1997
Journal of Geophysical Research Atmospheres.	5	607	1998
Current Problems in Remote Sensing of the Earth from Space.	5	109	2015
Environmental Modelling and Software.	4	188	2013
IEEE Geoscience and Remote Sensing Letters.	4	69	2005
Journal of Atmospheric Science.	4	109	2000
Sensors (Switzerland).	4	29	2017

Note: Number of articles (n); total citations (TC).

Table 4. Top 15 globally cited articles on EOS and PM studies from 1979–2019.

Satellite/EOS/Model	Findings/Gaps	Total Citation	Reference
Sentinel-2	The findings reveal the effectiveness of using Sentinel-2 in a global monitoring environment but unable to retrieve previous decades' data for a long time series.	1030	[77]
MODIS	The results show that MODIS products work better than AVHRR in monitoring global fire detection changes in the location and rate of biomass consumption by fires.	467	[83]
Landsat7-ETM+ images, NDVI, LAI, AET, ET_o	Findings demonstrate exponential relationships between LAI and NDVI, as well in LAI and plant transpiration coefficient (K_{cb}); good accuracy linear relationship on NDVI and K_{cb} to wheat phenology in the seasonal land cover using Landsat data. Such analysis approaches on a regional scale are limited by high resolution and visit time.	262	[80]

Table 4. *Cont.*

Satellite/EOS/Model	Findings/Gaps	Total Citation	Reference
AVHRR, SPOT-Vegetation, SeaWiFS, MODIS, Landsat ETM+. NDVI	Findings reveal a consistency in NDVI records derived in different satellites through statistical and correlation analyses for monitoring the surface vegetation.	247	[76]
COSMO-SkyMed	Findings show COSMO-SkyMed constellation contribution of the X-band SAR, fast response, and short revisit time for various agriculture monitoring applications.	153	[84]
Global Earth Observation System of Systems	The findings reveal the importance of knowledge and semantic formalization to address multidisciplinary applications (i.e., pasture change detection over time).	126	[85]
NASA Sensor Web	The findings showed the development of GeoSWIFT for the integration of remote sensing imagery and real-time in situ sensing observations of crop yielding.	114	[86]
Earth Observation System, MODIS, Land Science Team model, LAI	The results show the combination of remote sensing data with process-based and spatially distributed biogeochemistry models to examine variation in ecosystem processes. However, these process models can be validated against direct measurements made with eddy covariance flux towers and ground-based NPP sampling.	100	[87]
ASTER and MODIS. TES algorithm, TISIE algorithm	The results reveal the feasibility of merging ASTER and MODIS data for emissivity and radiometric temperature in semi-arid rangelands and agricultural areas.	98	[79]
Earth Observations	The findings show the significant role of Earth observation systems in supporting the 2030 Agenda directly addressing the sustainable development goals (SDGs).	87	[88]

Table 4. *Cont.*

Satellite/EOS/Model	Findings/Gaps	Total Citation	Reference
Advanced Spaceborne Thermal Emission Reflectance Radiometer	Findings demonstrate the ability of ASTER to provide science objectives identified by the EOS global change program such as surface reflected radiances and the application of digital elevation models for vegetation conditions.	85	[89]
LIDAR, Imaging spectrometer, Radiative transfer models, LAI	The findings specified robust estimates of the characteristics of the forest canopy characteristics that were achieved, ranging from maximal tree height, fractional cover (Fcover), leaf area index (LAI) to the foliage chlorophyll, and water content of the foliage for a wide range of pastures.	84	[81]
MODIS, LAI	The findings validate land cover and land use change models using MODIS data based on MODIS Land Discipline Group (MODLAND).	83	[90]
Environmental Mapping and Analysis Program (EnMAP) mission	Findings revealed the simulated tool of remote sensing images for hyperspectral and multispectral data called EnMAP to applications such as pasture monitoring.	77	[91]
Widefield view (WFV for GF-1), Prospect + Sail radiative transfer model	Findings show a high-quality fractional vegetation cover estimation algorithm using a physical model and neural networks through the first high-resolution EOS Chinese satellite (GF-1 data).	74	[78]

3.1.8. Top 20 Authors Keywords and Co-Occurrence Network

The information in Table 5 shows the top 20 authors' keywords on EOS and PM during the survey period. The author keywords were classified according to the author keyword (DE) and keyword Plus (ID). Remote sensing was ranked first and appeared most as a keyword term of the author (DE), accounting for n = 34, followed by Earth observation (n = 20) and global Earth observation systems (GEOSS) (n = 18), respectively. Remote sensing had the highest appearance in author keyword Plus (ID), accounting for n = 171, Earth observation accounting for n = 98, and EOS accounting for (n = 76), respectively. Accordingly, Earth observation and remote sensing revealed dominance in authors' keywords (DE) and keyword Plus (ID). However, these keyword terms indicate that Earth observation applications have been central in remote sensing and global change detection. In addition, remote sensing, Earth observation, climate change, and MODIS appeared more between the author's keyword (DE) and keyword Plus (ID). This may suggest that these variables highlight the relationship between remote sensing and Earth observation system in monitoring and modeling pasture dynamics under global change [92]. However, Sentinel-2, agriculture, big data, and mathematical model were rarely used in authors' keywords in EOS and PM research, which may suggest more studies for future development.

Table 5. Top authors keywords used on EOS and PM studies from 1979–2019.

Rank	Author Keywords (DE)	Articles	Author Keywords (ID)	Articles
1	Remote sensing	34	Remote sensing	171
2	Earth observation	20	Earth observation	98
3	Geoss	18	EOS	76
4	NDVI	9	Observations	71
5	Climate change	8	Satellite imagery	62
6	Interoperability	8	Satellites	54
7	Satellite	7	Earth (planet)	42
8	Geoss	6	Geoss	40
9	MODIS	6	Earth observations	31
10	Data sharing	5	Radiometers	31
11	Monitoring	5	Satellite data	31
12	Sentinel-2	5	MODIS	28
13	Agriculture	4	Calibration	27
14	AMSR-E	4	Climate change	27
15	Aster	4	Decision Making	24
16	Big data	4	Spatial resolution	24
17	Biodiversity	4	Environmental monitoring	23
18	Calibration	4	Orbit	21
19	Classification	4	Weather forecasting	21
20	Data management	4	Mathematical model	20

Figure 6 shows the top 20 keywords' co-occurrence in EOS and PM studies. The size of nodes depicts the frequency of keywords. The larger the size of the node, such as remote sensing and Earth observation, the higher the frequency of keywords. Soil moisture, agriculture, land cover, environmental management, and rain (precipitation) are the most common factors used as keywords and are influential in the field of EOS and PM studies. Other important variables, such as soil, leaf area index, drought, and temperature, among others, had a low frequency of keywords, suggesting more research for future development in EOS and PM studies.

3.1.9. Decadal Trending Topics of High-Frequency Keywords

Figure 7 shows the trending topics over the last decade in the EOS and PM studies. The decadal trending topics were generated based on the trending topics associated with the high frequency of the author's keyword in the field during the survey period. The frequency of authors' keywords on EOS and PM was summarized within the period of the analysis by a structured scheme to classify the core high-frequency keywords with a word frequency greater than or equal to 10 being selected. Therefore, 12 high keywords were obtained in terms of their occurrence in the field and drawn as decadal trending topics, as shown in Figure 7. This depicts the keywords and areas to identify in EOS and PM studies. It is worth noting that trending topics such as climate change, Earth observation, NDVI, remote sensing, MODIS, and Sentinel-2, among others have been included under EOS and PM studies. Accordingly, remote sensing was observed at the highest peak in terms of its frequent applications in EOS and PM studies during the survey period. In addition, it was observed that, between the years 2008 and 2018, EOS and PM studies gained increased global attention and significance in space-based technology and development in modeling pasture dynamics.

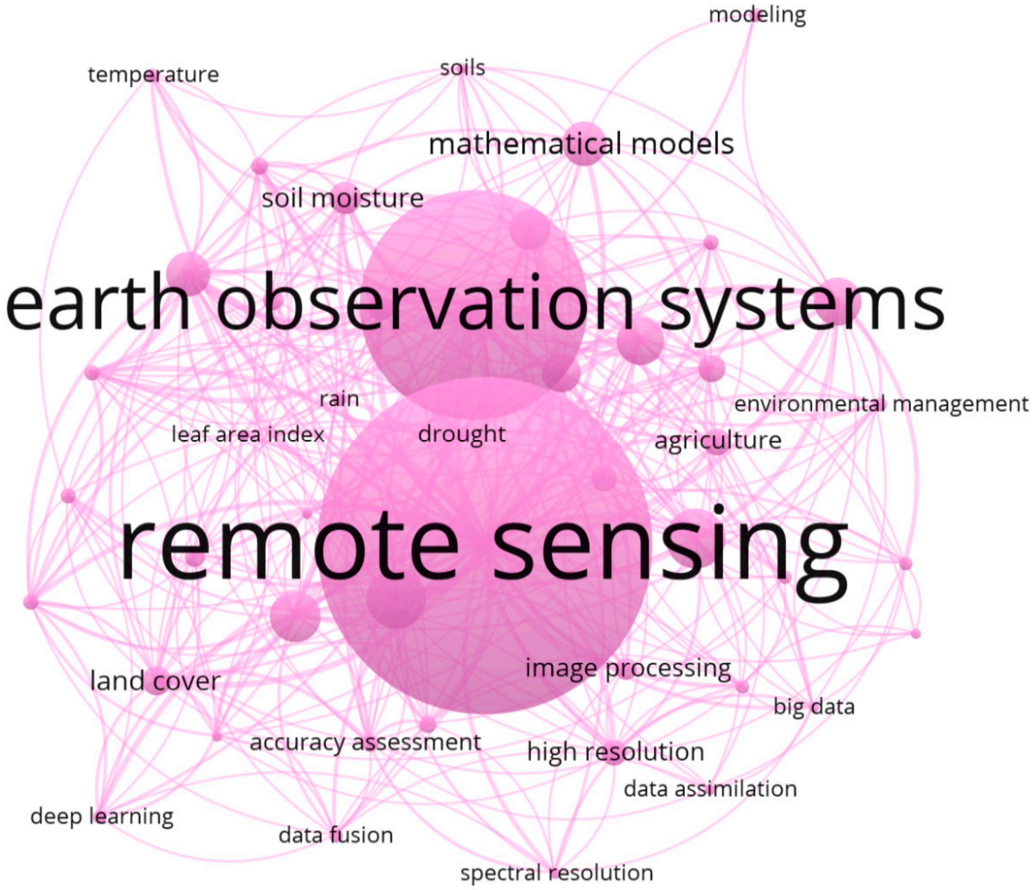

Figure 6. Top 20 keywords' co-occurrence network on EOS and PM studies.

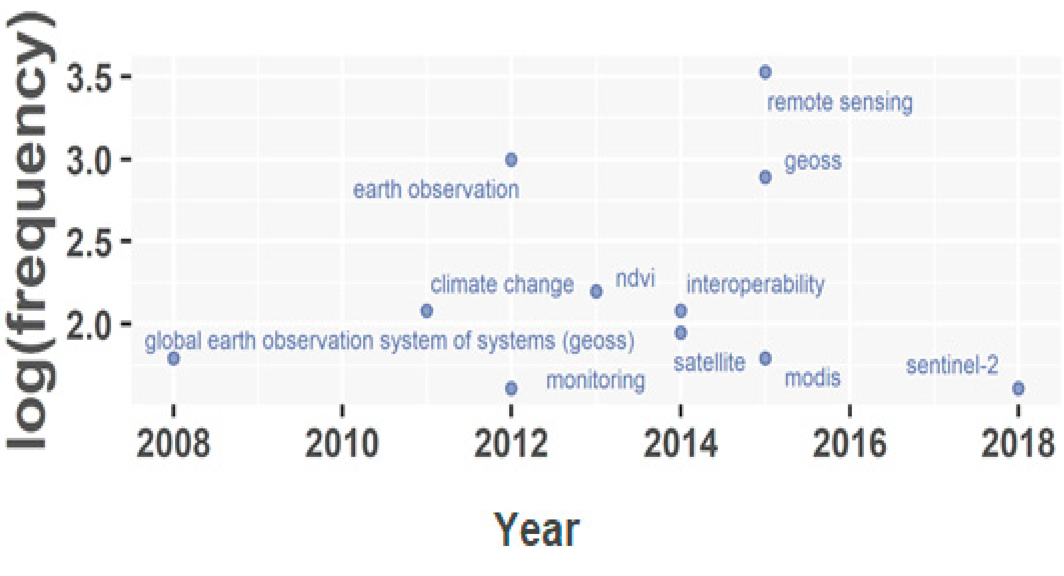

Figure 7. Decadal trending topics on EOS and PM studies.

4. Discussion

This study assessed a total of 399 published articles on EOS and PM studies, using the bibliometric method. A detailed analysis was carried out to evaluate the annual scientific production, author's contribution, top global cited published articles, author's keyword, trending topics, and co-occurrence of keywords in EOS and PM studies. The average growth per article of EOS and PM research showed inconsistency during the survey period, which suggests that the field was unstable in terms of average total citations per article. The observed decline in publication of EOS and PM studies between 1980 and 2019 cannot be generalized in terms of countries' publications. This may be linked with complex data structures, limited large-scale high-resolution sensors, and the lack of EOS designed for PM studies [40]. The highest average citation per article was 19.76%, suggesting that global research on EOS and PM has been increasing over the last decade, particularly between 2008 and 2018. The gradual increase in annual scientific production rate and average total citations on EOS and PM research resulted in increased production in terms of the number of publications and total citations per year over time. Progress in EOS and PM studies was at its highest peak in 2017 in terms of the number of publications, thus revealing the impact of recent EOS with an improved resolution for pasture modeling [41,93,94]. The results show that the USA, China, and Italy ranked the most cited and most productive authors in terms of average total citations and multiple country publications, which strengthened the research development in EOS and PM studies. Mexico, Thailand, Sri Lanka, Brazil, and other African nations had a low research output and single country publications on EOS and PM studies during the survey period. This reveals the need for these nations with low engagement to collaborate with nations in the global north to boost their research in EOS and PM to bolster the current food security initiatives. Furthermore, it is revealed that the USA developed the environment vulnerability decision technology (EVDT) to support environmental management decision-making and reduce the dual needs of processing data for monitoring surface changes on pasture dynamics [95,96]. Therefore, this justifies the USA's advance in EOS and PM, which depicts the country's advancement in space-based technology. Additionally, the USA has been at the center in recent spatiotemporal index developments for accelerating access to EOS big data assimilation to better understand Earth system and PM research [97]. This development may suggest that the author's keywords and the leading country's contribution to EOS and PM studies are an eye-opener to make room for other developing nations. Studies revealed that the Earth observation system race often varies between the USA, Europe, Asia, and North America in terms of advances in Earth observation and geoinformation science and technology [98,99]. The lack of investment in Earth observation systems for environmental monitoring decision-making could suggest the low publication rate for other developing countries on EOS and PM studies [99]. Remote sensing was observed to be the most appeared keyword in the field of EOS and PM studies. This is a demonstration that the contribution of remote sensing applications since 1978 in ecological research advances the synergy between EOS and PM studies [100,101]. This may have also contributed to the development of space-based technology and data assimilation techniques suitable for pasture modeling [41,102]. Furthermore, free access to EOS, such as Sentinel, Landsat, and MODIS, among others, contributed to pasture model research in terms of their applications to pasture management [80]. The use of remote sensing has the potential to influence policy makers to incorporate the use of remote sensing for strategic planning and minimize the impact of pasture degradation. The results of this study revealed the limitations of low-resolution satellite sensors such as AVHRR, Landsat, and MODIS, among others. However, these limitations might have affected the monitoring assessment of pasture modeling research on EOS and PM. Results further revealed that a series of authors' keyword terms and keywords' co-occurrence network help to identify factors such as soil moisture, climate change, and precipitation, among others affecting pasture dynamics in EOS and PM studies. However, the use of the author's keyword terms such as monitoring, Sentinel-2, agriculture, big data, and mathematical model has been scantly explored in EOS and PM studies. This may also suggest the recent development in

European Union (EU) programs and sentinel missions, including statistical models and machine learning to monitor pasture dynamics at multiple scales [9,41].

5. Conclusions

This study evaluated studies on EOS and PM to reveal the evolution and current research hotspot and better understand the dominant themes by using the bibliometric method to analyze published articles from l979 to 2019. The findings in this study would help to advance the understanding of evolutionary trends of these studies by assessing the intellectual domain and identifying the history of global scientific research history in EOS and PM studies. Furthermore, the study appraised published articles by assessing the annual scientific production, author's global citation, decadal trending topics, keywords' co-occurrence network, journal analysis, and institutions' and countries' collaboration associated with EOS and PM studies. Therefore, using these available articles on EOS and PM helps to identify the research gap. The reviewed studies were used to evaluate and determine the current research hotspots and dominant themes, considering the information from time-varying trends observed in EOS and PM during the study period. The important scientific findings from these studies show that Earth observation systems and remote sensing are in the central position in all keywords with the largest significant appearance in the field. This connotes that future studies must appraise how far the EOS has been able to contribute to the advancements of modeling pasture dynamics. Earth observation systems play an important role in pasture monitoring and development using remote sensing techniques for mapping and assessing degraded land. Advances in artificial intelligence, deep and machine learning may compensate for the assessment of big ensemble data assimilation using mathematical algorithms for future EOS and PM studies. The key findings are associated with the application of pasture modeling, as Earth observation systems provided important information of time-series satellite imagery associated with change detection of terrain characteristics of pastoral rangelands. This information may help to spatially delineate anomalies in pastoral conditions, as well as growth and development in both length and intensity at different temporal and spatial scales. Therefore, bibliometrics has been widely utilized as a methodological approach to evaluate various research niche areas over time. Consequently, the study provided information for individuals, institutions, and governments in understanding the current state of research on EOS and PM. The results of this study are crucial in planning and managing pastoral rangelands and forest ecosystems. This also serves as an eye-opener for those developing countries, especially African nations, who had little or no research on EOS and PM studies and to provide hints for future research. This article suggests that various research databases should be incorporated to identify other possible research developments within the area of focus.

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