ISSN: 2447-3359

REVISTA DE GEOCIÊNCIAS DO NORDESTE

Northeast Geosciences Journal

v. 6, nº 2 (2020)

https://doi.org/10.21680/2447-3359.2020v6n2ID20843

THE ADVANCE OF THE USE OF GEOSPATIAL TOOLS IN THE MANAGEMENT OF CONTINENTAL WETLANDS

Isadora Taborda Silva[1]; Dhonatan Diego Pessi[2]; Eliane Guaraldo[3]; Antônio Conceição Paranhos Filho[4]

[1]Mestre em Recursos Naturais, Programa de Pós-Graduação em Recursos Naturais, Universidade Federal de Mato Grosso do Sul (UFMS), Campo Grande/MS, Brasil.
ORCID: https://orcid.org/0000-0001-9053-4329
Email: isah.taborda@gmail.com

[2]Doutorando em Tecnologias Ambientais, Programa de Pós-Graduação em Tecnolofias Ambientais, Universidade Federal de Mato Grosso do Sul (UFMS), Campo Grande/MS, Brasil.
ORCID: https://orcid.org/0000-0003-0781-785X
Email: dhonatan.pessi@gmail.com

[3]Pós-Doutora em Gestão Urbana, Departamento de Estruturas e Construção Civil, Universidade Federal de Mato Grosso do Sul (UFMS), Campo Grande/MS, Brasil.
ORCID: https://orcid.org/0000-0003-2526-1293
Email: eliane.guaraldo@ufms.br

[4]Doutor em Geologia Ambiental, Faculdade de Engenharias, Arquitetura e Urbanismo e Geografia, Universidade Federal de Mato Grosso do Sul (UFMS), Campo Grande/MS, Brasil.
ORCID: https://orcid.org/0000-0002-9838-5337
Email: toniparanhos@gmail.com

Abstract

Continental wetlands are fundamental ecosystems for fauna, flora and the well-being of humanity. The understanding of this system is substantial for maintaining its balance and reducing possible anthropic impacts. This research aims to survey the progress of scientific publications on continental wetlands that use geotechnologies to analyze land use and cover. The main articles referred to two aspects: one about the creation, updating and improvement of techniques, methods and databases, and the other regarding the monitoring and evaluation of possible impacts. 2157 publications were found from the first publication in 1977 to the last one at the end of 2019. The set presented mostly results in article format, with a total of 71.74% (1548) of the publications, followed by 22.97% (495) of event annals, 1.86% (40) of book chapters, 1.72% (37) of review articles, and finally, 1.72% (37) of other types of documents. Research on land use and land cover in humid areas with geotechnologies has maintained an almost constant annual growth with a considerable citation average and exponential growth that indicates an intensification in the discussion on the topic.

Keywords: Remote sensing; flooded áreas; geoprocessing software.

O AVANÇO DO USO DE FERRAMENTAS GEOESPACIAIS NA GESTÃO DE ÁREAS ÚMIDAS CONTINENTAIS

Resumo

As áreas úmidas continentais são ecossistemas fundamentais para a fauna, flora e o bem-estar da humanidade. A compreensão deste sistema é substancial para a manutenção de seu equilíbrio e reduzir possíveis impactos antrópicos. Essa pesquisa objetiva levantar o progresso das publicações científicas sobre áreas úmidas continentais que utilizem geotecnologias para análise do uso e cobertura do solo. Os principais artigos se referiam a duas vertentes: uma sobre a criação, atualização e aperfeiçoamento de técnicas, métodos e bancos de dados, e a outra no tocante ao monitoramento e avaliação de possíveis impactos. Foram localizadas 2.157 publicações desde a primeira publicação em 1977 até a última no fim de 2019. O conjunto apresentou em sua maioria resultados no formato artigo, com um total de 71,74% (1.548) das publicações, seguido de 22,97% (495) de anais de evento, 1,86% (40) de capítulos de livros, 1,72% (37) de artigos de revisão, e por fim, 1,72% (37) de outros tipos de documentos. As pesquisas acerca do uso e cobertura do solo em áreas úmidas com geotecnologias têm mantido um crescimento anual quase constante com uma média de citação considerável e crescimento exponencial que indica uma intensificação na discussão sobre o tema.

Palavras-chave: Sensoriamento remoto; Áreas alagadas; Softwares de geoprocessamento.

EL AVANCE DEL USO DE HERRAMIENTAS GEOESPACIALES EM EL MANEJO DE HUMEDALES CONTINENTALES

Resumen

Los humedales continentales son ecosistemas fundamentales para la fauna, la flora y el bienestar de la humanidad. La comprensión de este sistema es sustancial para mantener su equilibrio y reducir

los posibles impactos antrópicos. Esta investigación tiene como objetivo estudiar el progreso de las publicaciones científicas sobre humedales continentales que utilizan geotecnologías para analizar el uso y la cobertura de la tierra. Los artículos principales se referían a dos aspectos: uno sobre la creación, actualización y mejora de técnicas, métodos y bases de datos, y otro sobre el monitoreo y la evaluación de posibles impactos. Se encontraron 2157 publicaciones desde la primera publicación en 1977 hasta la última a fines de 2019. El conjunto presentó principalmente resultados en formato de artículo, con un total de 71.74% (1548) de las publicaciones, seguido por 22.97% (495) de anales de eventos, 1.86% (40) de capítulos de libros, 1.72% (37) de artículos de revisión, y finalmente, 1.72% (37) de otros tipos de documentos. La investigación sobre el uso de la tierra y la cobertura de la tierra en áreas húmedas con geotecnologías ha mantenido un crecimiento anual casi constante con un promedio de citas considerable y un crecimiento exponencial que indica una intensificación en la discusión sobre el tema.

Palabras-clave: Teledetección; Áreas inundadas; Software de geoprocesamiento.

1. INTRODUCTION

Wetlands are zones where water is the main factor in the environmental control of the associated flora and fauna. Despite its importance, it is estimated that over 70% of global wetlands have already been destroyed or compromised since 1900 (GARDNER et al., 2015). Thus, studies on these areas are of great significance to protect them and reduce possible alterations. However, these are difficult areas to monitor through conventional methods, due to their relative inaccessibility and seasonal dynamics (HEWES, 1951; LEE e LUNETTA, 1996; MITCH e GOSSELINK, 2007). These hurdles make remote sensing a suitable type of analysis (FRANÇA e SANO, 2011; GUO, 2017). Its use in environmental studies is present in the specialized literature, enabling analyses and the elaboration and mapping of vegetation environmental impacts, among others.

Thereby, many researches have been carried out with the use of geoprocessing tools, of which remote sensing stands out often allied to field work, with the goal of assessing and monitoring them; Nevertheless, few have summarized the progress of researches on the matter. To fill in this gap, the present article aims to quantify the academic publications on continental wetlands where remote sensing is employed to assess soil use and cover. Additionally, the utilization of free software or lack thereof in these studies is also investigated.

In this sense, bibliometric analysis is an effective method to assess academic publications using statistical techniques and correlating them with specific subjects. It allows the measuring of academic performance in a determined field of science, shedding light on their structure and development pattern (ZHANG et al., 2015), and has been widely accepted for offering innovative perspectives in the assessment of research trends, through content analysis (MAO et al., 2015).

Therefore, this study aimed to quantify academic publications on continental wetlands where remote sensing tools are used to analyze the soil use and cover, to obtain a basis for the progress of researches on the topic.

2. METHODOLOGY

Bibliometrics and bibliometric indicators are jointly used to assess author productivity, create citation studies, and determine the quality of scientific journals (LOPES et al., 2012).

In bibliometric analysis, the main indicators are related to the citations in each publication, the impact factor (IF) of journals and the H index (h-index) of the researcher (WOOD JR e COSTA, 2015). These three factors were used in this study to verify the impact of scientific production, along with the data regarding year of publication, country of origin, and keywords of articles.

To better represent the universe of the study, some keywords were defined and presented in Table 1. Lastly, for string formation, the basis of the words and their possible variations present in the literature were considered. Due to the wide range of studies in English, the terms were used in this language.

Table 1 – Definition of the terms in English to be utilized for string formation, derived from the keywords in Portuguese, and their respective synonyms found in the literature. Source: the authors (2020)

TERMS	SYNONYMS IN INGLISH
Continental Wetlands	Wetland
Geotechnologies and Remote Sensing	Remote Sensing Geotecnolog* Geotechnolog* GIS Geoprocessing* Satellite Image*
Land Use and Cover	Land Use Land Cover LULC Soil Cover

Finally, the main search string was determined as: Wetland * AND ("Remote sensing" OR Geotecnolog* OR Geotechnolog* OR GIES OR "Satellite Image") AND ("land use" OR "land cover" OR "Soil cover").

The research was conducted on indexed bases available on the *Portal de Periódicos da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (Portal of Journals of the Coordination for the Improvement of Higher Education Personnel) – CAPES/MEC, whose access is made available to scholars, due to a partnership between CAPES and the Federal University of Mato Grosso do Sul – UFMS. Three great free databases in the academic scenario were initially selected: Scopus (ELSEVIER, 2020a), Science Direct (ELSEVIER, 2020b), and Web of Science – Main Collection (CLARIVATE ANALYTICS, 2020a). The searches were limited to titles, abstracts and keywords in works published until 2019 (Table 2).

Table 2 – Results of the string Wetland AND ("Remote sensing" OR Geotecnolog* OR Geotechnolog* OR GIES OR "Satellite Image") AND ("land use" OR "land cover" OR "Soil cover") in the databases. Source: Compilation of Scopus (ELSEVIER,2020a), Science Direct (ELSEVIER,2020b) and Web of Science (CLARIVATE ANALYTICS, 2020a).*

DATA BASE	RETURN
Science Direct	373 publications
Web of Science	1424 publications
Scopus	2157 publications

After downloading the records, saving the content 'Author, Title, Source and Abstract', these were organized on the Mendeley free software (ELSEVIER, 2020c), which manages references, allowing a bibliometric approach to assess research results and removing eventual duplicates. Prior to pre-selection, we realized that the Web of Science and Science Direct databases contained, in their majority, publications already existing in the Scopus database. Therefore, the latter was chosen as the key database of the research, using data referring to the types of documents, languages, covered areas of knowledge, keywords, country of authors, type of access and software used.

Subsequently, the VOSviewer free software (VAN ECK e WALTMAN, 2020) was employed as a bibliometric tool. It creates networks of co-citations from articles of certain databases, with information regarding bibliography, citations, abstracts, and keywords. Using this software aids in the construction of networks of co-authored relations between different countries and the recurrence of keywords.

After analyzing the general data analysis, the most cited articles were picked to draw a panorama on the main discussions regarding the subject matter. For the 10 most cited works in the publications, each was given a Journal Impact Factor (JIF) and the H-index of the author, as it was considered that author's influence could also be significant in the dissemination of the article. Due to the scarce information on the authors' H-index in the Scopus database, the data found in the Google Scholar database was considered, since it is a search source built by researchers themselves, thus being reliable and valid to disseminate researches and consult data. For each article, the highest H-index among the authors was selected, as well as the citations found in the Scopus database (ELSEVIER, 2020a) up until searches done in January 2020.

Having discussed the main articles published on the matter over the years, a new trendline in publications within the last four years was searched (2016-2019). Once again, the most cited articles in those years were surveyed, as well as the JIF and highest H-indexes, among those found in the Google Scholar database (GOOGLE, 2020).

Afterwards, we sought to identify which of these publications mentioned the software employed in the research and how many were free or open sourced. According to the Free Software Foundation (2019), the advantages of using these software are countless, as opposed to using proprietary software (which require purchasing before access). In addition to not adding costs to researchers, those which are open sourced allow changes to better adapt to the user. The corrections to the software make them faster and more efficient, thanks to the sharing culture between users and developers.

From the start, the main string was refined with the term software, as it was noted that few of the articles cited which ones they had utilized in the study. With 250 resulting documents, the ones employing free or open sourced software were set aside, using another refinement. The terms used in the second refinement were: ("Free software" OR "Open source" OR "Open software" OR "Freeware"). Then, the 18 resulting documents were analyzed.

3. RESULTS AND DISCUSSION

3.1. Quantitative analysis

Overall, 2,157 publications were identified, from the earliest in 1977 to the latest in late 2019. As shown in Figure 1, the set presented, in their majority, results in the format of articles, with a total of 71.74% (1,548) of the publications, followed by 22.97% (495) of event annals, 1,86% (40) of book chapters, 1.72% (37) of review articles and, lastly, 1.72% (37) of other types of documents. To obtain a cleaner result, the analysis only accounted for scientific articles and review articles (1,585 articles).

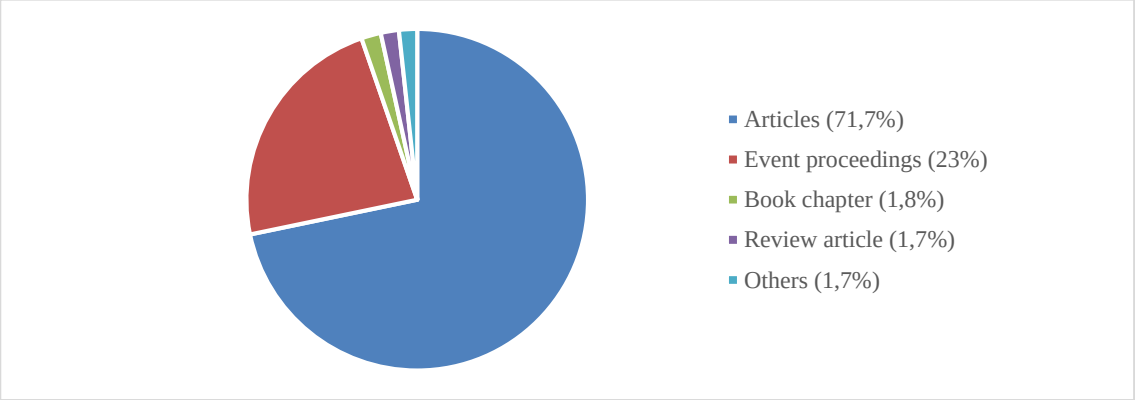

Figure 1 – Graph with the formats of documents found in Scopus, where the majority of the publications were identified as articles. Source: Compiled from the Scopus Database (ELSEVIER,2020a).

The number of publications per year (PY) maintained a near-constant annual growth (Figure 2). From 1977 to 1995, it maintained and average of 2,74 PY. After this period, this average rose to 15,62 PY until the year of 2003, and afterwards, it quadrupled to 65,45 PY from 2004 to 2014. In the last 5 years, the average has grown again, doubling in size, and reaching its peak with 137,2 PY. The three most productive years are in this last time frame, with 2019 at 169 PY, followed by 2018 at 135 PY and 2015 at 132 PY.

Allied to the steady growth in publications, is that of citations. Overall, the 1,585 publications add up to 34,990 citations, with an average of 22,10 citations per item. When comparing the total of citation per year (CY) with that of PY in Figure 3, we can see that the first citations occurred soon after the beginning of publications, but only started to become expressive in the 2000s. In the last seven years, the amount of citations doubled from 2,130 citations/year in 2014 to 5,494 in 2019, indicating an intensification of the discussion on the subject matter.

Th publications cover 23 fields of science, with a single document being able to approach multiple fields at once (Figure 4). Amongst them, Environmental Sciences stands out with nearly a third of the publications and emerging 936 times (34.04%), followed by Geosciences with 570 occurrences (20.73%) and Agrarian and Biological Sciences with 527 instances (19.16%). Altogether, the other 20 fields of knowledge totalize 717 publications (26.07%).

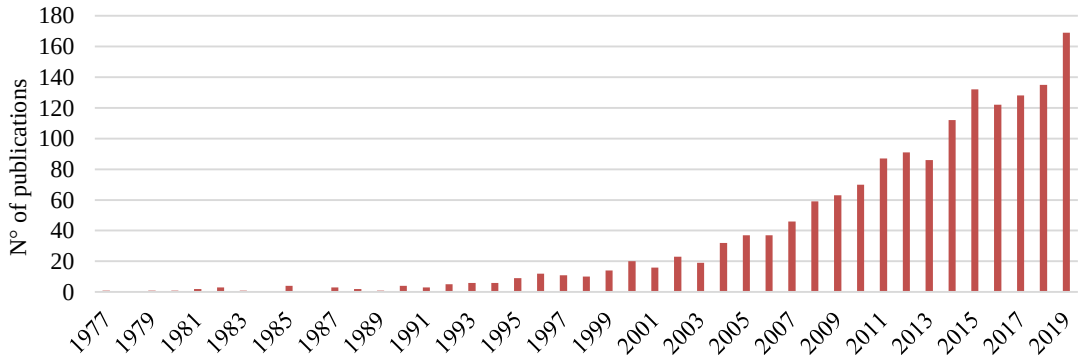

Figure 2 – Graph of publications per year, representing the steady growth of works on the subject. Publications began in 1977 but became constant in the 90's. The last five years (2015-2019) were the most productive and reached an average of 137,2 publications per year. Source: Compiled from Scopus (ELSEVIER,2020a)

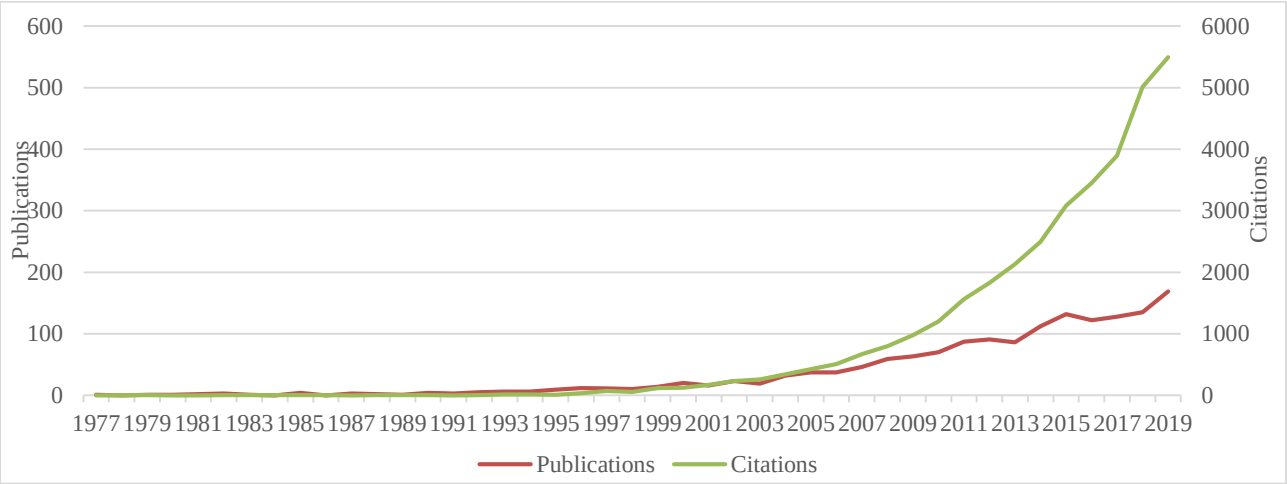

Figure 3 – Graph of the combination where the left vertical axis represents the amount publications per year, and the right axis represents citations per year. The peak of citations in 2019 corresponds to a value around 30 times greater than that of publications in the same year, evidencing the recurrence of the subject. Source: Compiled from the Scopus Database (ELSEVIER,2020a)

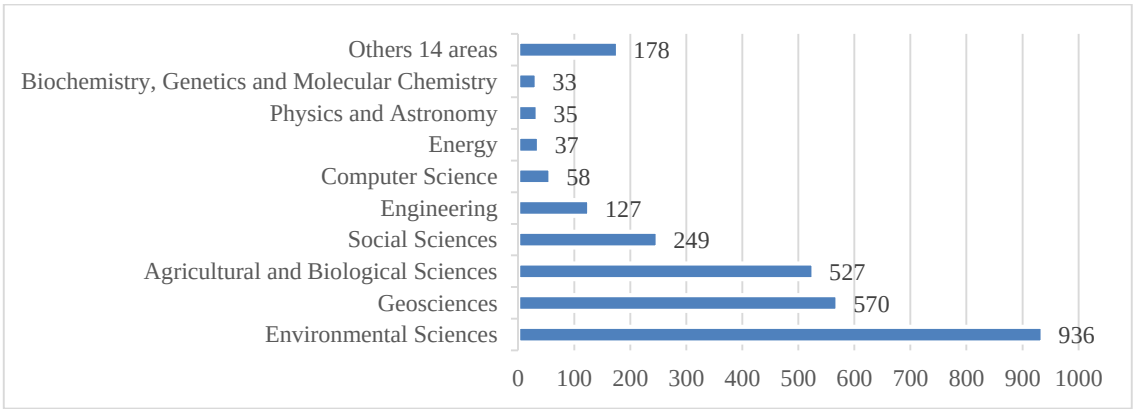

Figure 4 – Graph of the fields of science covered in the publications. Environmental Sciences stands out as composing a third of the articles. Source: Compiled from the Scopus Database (ELSEVIER,2020a)

Among the main languages of the publications, according to the authors, English strikes with 1,371 works (86%), despite being the official language of only 6 of the 15 countries with the highest number of publications. Chinese also stands out with 185 publications (11.6%) and only a very small amount of works are found in other languages, such Spanish, French, German, Portuguese, Arabic, Persian, Polish, Japanese, Russian, Slovakian and Hungarian, which altogether correspond to 2.4% of the total (37 articles).

In their totality, the 15 countries with the highest number of publications hold 75.3% of the articles on the subject. The US, China and Canada lead this quantitative ranking (Table 3).

The US is the country with the most publications and citations, with triple the citations of runner-up China, which has a similar number of publications. Thus, the average of citations per item in China is the lowest among the Top 4, being superior only to that of India and Iran. Still analyzing the averages, the UK (6th), Canada (3rd) and Germany (4th) are the countries with the highest average of citation per item, indicating that they are the countries with the most influential publications. With 36 published documents, Brazil ranks 10th, tied with the Netherlands in number of publications, but with a lower average of citations.

Utilizing this network analysis, the relationship of international cooperation among the authors was also investigated. For the creation of this study, 35 countries with 10 or more publications were selected. To enhance visualization, it was also stipulated that these countries should possess, at least, three co-authorship connections, of which the following were excluded: Turkey (co-authoring only with the US), Argentina (cooperation with the US and Spain), Greece (cooperation with Sweden) and South Korea (no connections). Thereby, 31 of the 109 countries (28%) met the specific requirements, resulting in Figure 5.

Table 3 – The fifteen countries with the largest amount of publications. The US and China lead the group, having together around 50% of the total. Source: Compiled from the Scopus Database (ELSEVIER, 2020a)

COUNTRY	TOTAL OF PUBLICATIONS	TOTAL OF PUBLICATIONS (%)	TOTAL CITATIONS	AVERAGE OF CITATION/ITEM
United States	507	24,3%	20012	39,47
China	493	23,6%	6735	13,66
Canada	108	5,2%	4919	45,55
Germany	71	3,4%	3193	44,97
India	58	2,8%	613	10,57
United Kingdom	49	2,3%	2713	55,37
Australia	41	2,0%	863	21,05
France	38	1,8%	689	18,13
Netherlands	36	1,7%	1180	32,78
Brazil	36	1,7%	677	18,81
Turkey	33	1,6%	1139	34,52
Japan	29	1,4%	1004	34,62
Espain	27	1,3%	414	15,33
Iran	25	1,2%	81	3,24
Mexico	23	1,1%	601	26,13
Others 84 countries	516	24,7%	-	-

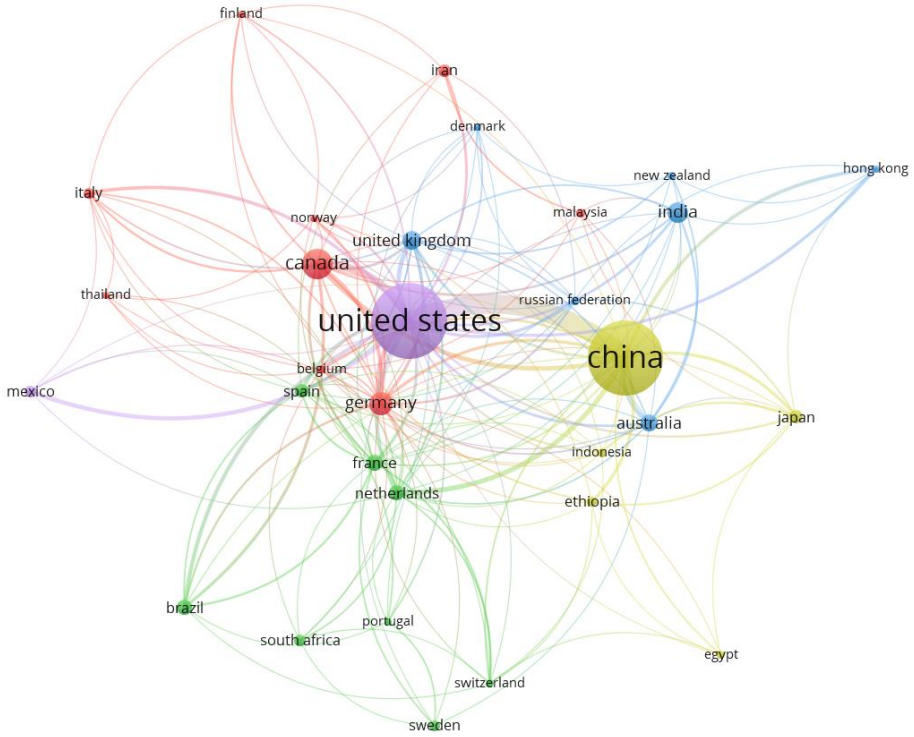

Figure 5 –Bibliometric networks analysis where the nodes correspond to the 31 countries with over 10 publications and 2 co-authorships, and the links symbolize the cooperation between them. Germany stands out, cooperating with 27 countries, with those being the ones with the highest amount of international co-authorship. Designed on VOSviewer (VAN ECK e WALTMAN, 2020) with data compiled from Scopus (ELSEVIER,2020a)

The nodes correspond to the countries, the dimension being defined by their total amoung of publications. The edges among them refer to the co-authorships, where the thicker the edge, the more connections between the countries. The clusters were defined by the software according to the affinity in publication between the countries, separating them in groups of 5 colors.

With the greatest amount of cooperation relationships, Germany stands out with connections to 27 of the 31 countries analyzed, among which are US, China and Canada, countries with the largest amount of publications. It is also associated with the United Kingdom, which, alongside Canada, form the trio with the highest average of citations per item, displaying the cooperation among the countries with most influential publications.

Researches from the United States of America co-write with 26 countries, with the highest flow of cooperation being with China, which is indicated by the thickest linking edge. Other connections include Canada, with whom they have the second highest flow of cooperation, followed by Mexico, the UK, Germany, the Netherlands, Brazil, and France.

Brazil maintains eight international co-authoring connections, co-writing with the US, Canada, Germany, France, Spain, Switzerland, Portugal, and China. The largest flow is with the US; however, the different between fluxes is insignificant. Among the Brazilian research groups, those who stand out are the National Space Research Institute (NSRI) with 10 research papers, the University of São Paulo (USP) with 4 papers, and with 2 publications each, the Federal Universities of Rio de Janeiro (UFRJ), Mato Grosso (UFMT), Rio Grande do Norte (UFRN), and the universities of Brasília (UNB) and the Paulista State University (UNESP).

While still using the network analysis system, the most evidenced keywords were listed. The words used for the string were excluded (wetland, remote sensing, land use, GIS, land cover, satellite image), for representing our search terms and being present in most of the articles as keywords. Finally, words repeated at least 80 times were selected, which resulted in 27 words from the remaining 10,045 (Figure 6).

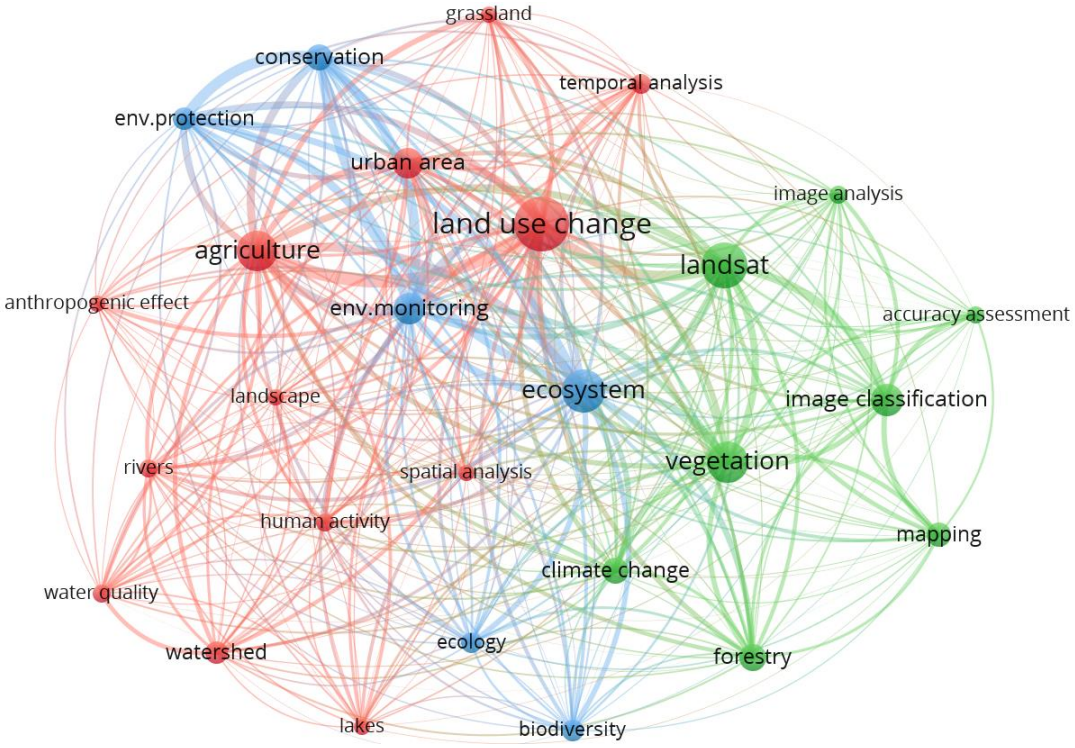

Figure 6 – Network analysis of the 27 main keywords, excluding the string terms. On the center, the more commonly used ones: Land use change, Landsat, ecosystem, and agriculture. Source: Designed on VOSviewer (VAN ECK e WALTMAN, 2019) with data compiled from Scopus (ELSEVIER,2020a)

Present in 352 articles and being a central elemental of the network is the term “Land use change”. Mainly connected with “Agriculture”, being linked with “Ecosystem” and “Environmental Monitoring”, it indicates that a great share of articles on the subject approach the advance in the agricultural field, under the native resources and the monitoring of possible impacts on the area. The great recurrence of the term “Landsat” (satellite imagery program of the American government) makes it, possibly, the main satellite image in use, largely allied to ‘Land use change, ‘Image Classification’ and ‘Vegetation’. Another

frequent link is that between 'Ecosystem' and 'Environmental Monitoring' and 'Climate change', as well as the link between 'Environmental Protection' and 'Environmental Monitoring', 'Conservation' and 'Agriculture'.

3.2. Main publications on the theme

The amount of citations are references that help to find works of greater visibility and credibility. For a historical analysis on the subject, the 10 most cited publications were selected (Table 4).

As seen on the table, the Journal Impact Factor (JIF) and H-index of the authors were also analyzed, since these aspects can influence the dissemination of the article. Due to lack of information on the earlier authors, the highest H-index found in the Google Scholar platform were considered (GOOGLE, 2020).

The journal "Nature" has the highest JIF among the 10 selected, and the most recent publication (2016). "Remote sending of environment" has the second highest HIF among the journals and four publications listed. On average, the journals' JIF is of 9,296 and the H-index of authors is of 68,2. It should be noted that, in general, each publication has at least one author with a considerable amount of published works and a significantly higher H-index when compared to the rest, possibly being the advisor or coordinator of these research groups.

Table 4 – The ten most cited articles with the number of citations, highest H-index among the authors, and journal impact factor. Source: Compiled from the Scopus Database (ELSEVIER, 2020a), Google Scholar (GOOGLE, 2020), and InCites Journal Citation Reports (CLARIVATE ANALYTICS,2020b)

ARTICLE	CIT. (até Jan.2020)	H-index	FI (JCR)
FRIEDL, M. A. *et al.* MODIS Collection 5 global land cover: Algorithm refinements and characterization of new datasets. Remote sensing of Environment, v. 114, n. 1, p. 168-182, 2010.	1.494	65	8.218
LEHNER, B.; DÖLL, P. Development and validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrology, v. 296, n. 1-4, p. 1-22, 2004.	1.002	59	4.405
OZESMI, S. L.; BAUER, M. E. Satellite remote sensing of wetlands. Wetlands ecology and management, v. 10, n. 5, p. 381-402, 2002.	616	50	2.250
ROTH, N. E.; ALLAN, J. D.; ERICKSON, D. L. Landscape influences on stream biotic integrity assessed at multiple spatial scales. Landscape ecology, v. 11, n. 3, p. 141-156, 1996.	580	64	4.349
OLOFSSON, P.; FOODY, G.; HEROLD. M.; STEHMAN; S.V.; WOODCOCK, C.E.; WULDER, M.A. Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment, v. 148, p. 42-57, 2014.	564	80	8.218
YUAN, F.; SAWAYA, K.E.; LOEFFELHOZ, B.C.; BAUER, M.E. Land cover classification and change analysis of the Twin Cities Metropolitan Area by multitemporal Landsat remote sensing. Remote sensing of Environment, v. 98, n. 2-3, p. 317-328, 2005.	546	50	8.218
WALKER, D. A. *et al.* The circumpolar Arctic vegetation map. Journal of Vegetation Science, v. 16, n. 3, p. 267-282, 2005.	507	69	2.944
DEWAN, A. M.; YAMAGUCHI, Y. Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to promote sustainable urbanization. Applied geography, v. 29, p. 390-401, 2009.	381	35	3.068
PAUSTIAN, K.; LEHMANN, J.; OGLE, S.B; REAY, D.; ROBERTSON, G.P.; SMITH, P. Climate-smart soils (Review). Nature, v. 532, Issue 7597, p. 49-57, 2016.	375	118	43.070
KASISCHKE, E. S.; MELACK, J. M.; DOBSON, M.C. The use of imaging radars for ecological applications—a review. Remote sensing of environment, v. 59, n. 2, p. 141-156, 1997.	312	92	8.218

Half of these articles have only authors from a single country (the US or Japan). In four of them, authors come from two countries, such as the US/Canada, US/Germany, US/UK, and US/Turkey. The article "The Circumpolar Artic Vegetation Map" is the one with the largest collaboration network, with 13 authors,

from the US, Germany, Iceland, Norway, Puerto Rico, and Russia.

The article with the most citations is "MODIS Collection 5 global land cover: Algorithm refinements and characterization of new datasets", published in 2010 and one of the newest on the list. In it, Friedl et al. (2010) describe the sets of data and algorithms used to create the MODIS Global Land Cover Type (NASA) and its alterations up until Collections 4 and 5. These tests were carried out to demonstrate the better efficacy of the latest collection. The article cited continental wetlands, relating them to specific cases, those that are problematic and hard to map, requiring the lowering of the threshold to classify the pixels.

Lehner e Döll (2004) presented a new database identified as the Global Lakes e Wetlands Database (GLDW), focused on three levels: large lakes and reservoirs, smaller water bodies, and wetlands. Hence, data from other databases, records and inventories that possessed descriptive characteristics on the areas were used, combined with maps (analogical or digital) and their spatial extensions.

Ozesmi e Bauer (2002) wrote the first review article on the list, comparing the classification methods and best techniques for thereof.

Roth, Allan and Erickson (1996) assessed the conditions of a watershed and the environmental impact of agriculture in the region using IBI (Index of Biotic Integrity) and HI (Habitat Index) indices. They inspected 23 confluences and categorized them in terms of the integrity of the streams and quality of the environment, according to the agricultural extent, wetlands, and forests.

Olofsson et al. (2014) standardized in their review several recommendations for designing and implementing methods for assessing accuracy and area estimation, which the authors called recommendations of good practice.

Yuan et al. (2005) mapped and analyzed the changes in an urban area using multitemporal analysis of different cities in the metropolitan area of Minnesota from 1986 to 2002, utilizing Landsat images. It is the first work on the list to reference the GIS Software, using ERDAS IMAGINE (HEXAGON).

Walker et al. (2005) outlined the main vegetation units in the Arctic and, utilizing ArcInfo (ESRI), generated a classification by NOAA VHRR images of the region.

With a temporal series of Landsat imaging, Dewan and Yamaguchi (2009) assessed the changes in soil cover and use in the urban extent of Greater Dhaka/Bangladesh and their dynamics.

In the most recent publication, Paustin et al. (2016) reviewed the potential mitigation of the Greenhouse effects on the soil. They highlight researches on gasses, summarize practices and the potential for mitigation, identify gaps in data and its comprehension, and even suggest new researches, technologies, and collaborations.

Lastly, Kasischke et al. (1997) examined publications that used synthetic-aperture radars for the investigation on eco-systemic processes and later divided them into four major categories: classification and detection of changes on land cover, estimation of the woody plants biomass, monitoring of the moment of flooding and its extent, and monitoring of other temporarily dynamic processes.

In summary, publications usually refer to two strands of thought: one on the creation, update and improvement of techniques, methods, and databases, and the other on the monitoring and evaluation of possible impacts.

3.3. Trends on the subject matter

To analyze the trends of the theme, as well as to loate any gaps, the five most cited publications of the last four years of research, out of 554 (2016-2019), were analyzed (Table 5).

The journal "Nature" is the one with the highest JIF and leads the list with the review article "Climate-smart soils" by Paustian et al. (2016), which is the 9th most cited in the historical analysis (Table 4). In sequence, the journal "Proceedings of the National Academy of Sciences of the United States of America" exhibits the second highest JIF on the list. In general, the publication presents an average of 160,6 citations and a JIF of 12,341.

The average H-index among noteworthy researchers of the last four years is of 53,25, remaining close to the previously cited historical analysis of 68,2. However, contrastingly to what was verified on the prior analysis, we observed that most authors either don't have their H-index information or there was no significant enhancement among them in the research groups. Thus, it is possible to infer that these groups differ from the previous ones, by presenting more influential researchers and less of a group leader. It should also be mentioned that none of the authors of the article "Assessment of soil erosion change and its relationships with land use/cover change in China from the end of the 1980s to 2010" (WANG et al., 2016) had any information on the Google Scholar platform (GOOGLE, 2020). Regarding nationality and co-authorship between different countries, three out of the five articles had authors from two countries.

Richards and Friess (2016) combined GIS tools and methods of remote sensing to quantify the mangrove deforestation in southwest Asia from the 2000s to 2012. The research identified a loss of 0.18% per year of mangrove forests. The rapid expansion of rice agriculture and growing palm oil plantations are the main causes of deforestation. It is the first article among those cited to specifically discuss wetlands.

Subsequently, Ottinger et al. (2016) reviewed the subject of Agriculture, shedding light on its relevance. They approach the positive aspects of creating aquatic products to avoid loss of costal wetlands and the pollution of water and soil. The article also points out the potential of remote sensing for monitoring these areas on a large scale.

Tian et al. (2016) presented the long-term impacts of Chinese coastal areas, through multitemporal analysis between 1985 and 2010. The study provides spatial and temporal distributions on these areas and analyzes factors such as coastal economy, populational growth, and the urbanization of regions directly related to it. The continued use of long-scale brought about countless negative environmental effects and indicates potential for future disasters related to coastal flooding.

Lastly, Wang et al. (2016) made use of an empirical approach to analyze soil erosion in relation to land use and changes in China between 1980 and 2010. Hydraulic erosion is widely found in the country, followed by wind erosion and frosting, and thawing. The majority of the alterations caused by erosion are concentrated on the mountainous regions of southern China, and on the northern

regions that have more fragile ecosystems, such as Loess Plateau, the deserts of Mu Us, Hunshandake and Horqin, a wetland of Xianghai and basin of the Tarim river.

Table 5 – The five most cited articles between 2016 and 2019, with the number of citations, highest h-index among authors and journal impact factor. Source: Compiled from Scopus (ELSEVIER, 2020a), Google Scholar (GOOGLE, 2020) and InCites Journal Citation Reports (CLARIVATE ANALYTICS,2020b)

ARTICLE	CIT. (until Jan 2020)	H-index	FI (JCR)
PAUSTIAN, K.; LEHMANN, J.; OGLE, S.B.; REAY, D.; ROBERTSON, G.P.; SMITH, P. Climate-smart soils (Review). Nature, v. 532, Issue 7597, p. 49-57, 2016.	375	118	43.070
RICHARDS, D.R.; FRIESS, D.A. Rates and drivers of mangrove deforestation in Southeast Asia, 2000-2012. Proceedings of the National Academy of Sciences of the United States of America, v. 113, n. 2, p. 344-349, 2016.	165	22	9.580
OTTINGER, M.; CLAUSS, K.; KUENZER, C. Aquaculture: Relevance, distribution, impacts and spatial assessments - A review. Ocean and Coastal Management, v. 119, p. 244-266, 2016.	77	44	2.595
TIAN, B.; WU, W.; YANG, Z.; ZHOU, Y. Drivers, trends, and potential impacts of long-term coastal reclamation in China from 1985 to 2010. Estuarine, Coastal and Shelf Science, v. 170, p. 83-90, 2016.	75	29	2611
WANG, X. *et al*. Assessment of soil erosion change and its relationships with land use/cover change in China from the end of the 1980s to 2010. Catena, v.137, p. 256-268, 2016.	66	-	3851

3.4. Main national publications

To obtain the base of national scope, the 3 most cited publications from the 36 publications made by Brazilian researchers were analyzed (Table 6).

The articles are published in journals with a high JIF, with the journal "Remote sensing of environment" leading the category with the most cited article. Overall, the average number of citations is 175 and a JIF of 5,671. Regarding the H-Index, the average is of 66, remaining close to the historical analysis (68) and the analysis of the most cited publications in recent years (53.25). The three publications involve researchers from the National Institute for Space Research (INPE) with scholars from research institutes in the United States.

Table 6 - The three most cited national articles until 2019 with the number of citations, the highest H-index among the authors and the journal's impact factor. Source: Compiled from Scopus (ELSEVIER, 2020a), Google Scholar (GOOGLE, 2020) and InCites Journal Citation Reports (CLARIVATE ANALYTICS, 2020b)

ARTICLE	CIT. (until Jan 2020)	H-index	FI (JCR)
WESSELS, K.J.; DE FRIES, R.S.;, DEMPEWOLF, J.A; ANDERSON, L.O.; HANSEN, A.J.; POWELL, S.L.; MORAN, E.F. Mapping regional land cover with MODIS data for biological conservation: Examples from the Greater Yellowstone Ecosystem, USA and Pará State, Brazil. Remote Sensing of Environment, v 92, n. 1, p. 67-83, 2004.	91	30	8.218
HESS, L.L.; MELACK, J.M.; AFFONSO, A.G.; BARBOSA, C.; GASTIL-BUHL, M.; NOVO, E.M. Wetlands of the Lowland Amazon Basin: Extent, Vegetative Cover, and Dual-season Inundated Area as Mapped with JERS-1 Synthetic Aperture Radar. Wetlands, v. 35, n. 4, p. 745-756, 2015.	80	94	1.854
LI, G.; LU, D.; MORAN, E.; DUTRA, L.; BATISTELLA, M. A comparative analysis of ALOS PALSAR L-band and RADARSAT-2 C-band data for land-cover classification in a tropical moist region. ISPRS Journal of Photogrammetry and Remote Sensing, v. 70, p. 26-38, 2012.	75	74	6.942

The work developed by Hess et al. (2015) presented the first validated mapping, of moderate high resolution, covering the extent of wetlands, vegetation cover and flooding conditions of the entire lowland Amazon basin. It can be considered a research of great relevance in a biome little studied in relation to humid areas.

Li et al. (2012) addressed in their research the prevailing difficulties in working with radar data and the importance of combining radiometric and textural images in the classification of soil cover in humid tropical regions. They report that, in general, L-band data provides a much better classification than C-band. However, neither L-band nor C-band data can accurately separate detailed forest classes (for example, upland forest, flooded forest, and forests vines) or succession (for example, SS1, SS2 and SS3).

Finally, the research conducted by Wessels et al. (2004) investigated the application of MODIS data for mapping regional territorial coverage in moderate resolutions (250 and 500 m), for regional conservation purposes in two main areas (Greater Yellowstone Ecosystem - GYE, USA and the state of Pará, Brazil) using MODIS data and decision tree classifications. According to the authors, land cover maps derived from MODIS have been successful in mapping extensive types of cover and, although not so much in mapping smaller types of cover (for example wetlands and deciduous forest), which normally occur in smaller patches than MODIS pixels.

3.5. Representativity of free software

Through a refinement on the main string, 1,585 papers were analyzed, seeking to find out which of these mentioned software use. This first refinement resulted in 250 publications. Using a second refinement, the ones citing free software were separated.

This resulted in 18 publications, where 8 cited the term on the bibliographical references, with 7 of them using proprietary software, and three not specifying the programs used. There was also one document unavailable for consultation. Lastly, only 7 out of the 250 articles of the first refinement used free software (Figure 7).

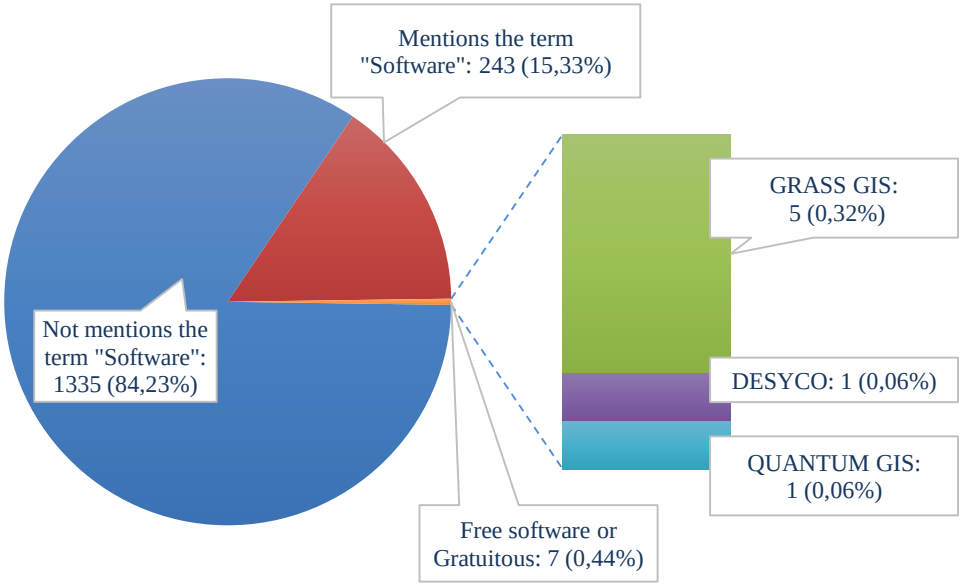

Figure 7 – Graph of the representativity of free software, where only 7 publications out of the 1,585 made use of free programs. Source: Compiled from the Scopus Database (ELSEVIER, 2020a)

Amongst them, the GRASS GIS software (NETELER e MITASOVA, 2013), acronym for Geographic Resources Analysis Support System, can be emphasized as a free and open-sourced software, and was used on five out of the nine articles found.

4. FINAL CONSIDERATIONS

Researches regarding the use of soil and cover in wetlands with the use of geotechnologies have grown steadily each year, with a considerable average of citations and exponential increase, indicating an intensification in the discussion on the topic.

In general, the most common publications are scientific articles and review articles, with English as the predominant language. The publications cover 23 areas of science, with many documents involving multiple areas.

The United States of America and China are the countries with the most publications and, together, make up almost 50% of the articles on the subject. The United Kingdom also stands out with the highest average of citations per item, and Germany, with the most co-authorship collaborations. Brazil is the only country in South America to be among the main 15, ranking 10th in overall publications. The cooperation relations indicate that a fair share of researches involves a large number of scholars of diverse nationalities.

Analyzing the main publications throughout the entire period, the presence of key figures such as advisors and coordinators in research groups stands out. These hold more publications and considerably higher H-indexes, when compared to the rest. However, when analyzing the last few years, a shift can be seen in this scenario, with the presence of more influential researchers within a single group.

The main publications mainly refer to two strands of thought: one on the creation, update and improvement of techniques, methods, and databases, whereas the other comprises the monitoring and evaluation of possible impacts. The network analysis of keywords pointed out 'Land use change' as more recurrently linked to 'Agriculture', indicating a fair share of works regarding the advances on agricultural areas under native resources. The great recurrence of the term 'Landsat' makes it the leading satellite imagery in use.

The scare existence of records on the software used in the researches shows little concern with the subsequent reproduction of these studies. The search for free software revealed few results and even less intention in helping to disseminate these researches.

5. REFERENCES

CLARIVATE ANALYTICS. *In Web of Science Core Collection.* 2020a. Disponível em: <https://login.webofknowledge.com/>. Acesso em: 2 jan. 2020.

CLARIVATE ANALYTICS. *In Cites Journal Citation Reports.* 2020b. Disponível em: <https://jcr.clarivate.com/>. Acesso em: 3 jan. 2020.

Dewan, A. M.; Yamaguchi, Y. Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to promote sustainable urbanization. *Applied geography*, v. 29, 390-401, 2009.

ELSEVIER BV. *In Scopus Database***.** 2020a. Disponível em: <https://www.scopus.com/>. Acesso em: 2 jan. 2020.

ELSEVIER BV. *In Science Direct Database*. 2020b. Disponível em: <https://www.sciencedirect.com/>. Acesso em: 2 jan. 2020.

ELSEVIER BV. *In Mendeley Desktop v1.19.3.* 2020c. Disponível em: <https://www.mendeley.com/>. Acesso em: 2 jan. 2020.

França, A. M. DA S.; Sano, E. E. Influência de variações ambientais sobre o fluxo de CO2 em solos sob Campo Limpo Úmido no Cerrado. *Sociedade e Natureza*, v. 2, 197–209, 2011.

Friedl, M. A. *et al.* MODIS Collection 5 global land cover: Algorithm refinements and characterization of new datasets. *Remote sensing of Environment*, v. 114, n. 1, 168-182, 2010.

Gardner, R. C.; Barchiesi, S.; Beltrame, C.; Finlayson, C. M.; Galewski, T.; Harrison, I.; Paganni, M.; Perennou, C.; Pritchard, D. E.; Rosenqvist, A.; Walpole, M. State of the World's Wetlands and their Services to People: A compilation of recent analyses. *Ramsar Briefing Note*, n. 7, 1-19, 2015.

GRASS Development Team, 2017. Geographic Resources Analysis Support System (GRASS) Software, Version 7.2. Open Source Geospatial Foundation. Electronic document:. http://grass.osgeo.org

GOOGLE. *In Plataforma Google Acadêmico*. Disponível em: <https://scholar.google.com.br/>. Acesso em: 3 jan. 2020.

Guo, M.; Li, J.; Sheng, C.; Xu, J.; Wu; L. A Review of Wetland Remote Sensing. *Sensors*, n. 17, 777, 2017.

Hewes, L. The northern wet prairie of the United States: Nature, sources of information, and extent. *Annals of the Association of American Geographers*, v. 41, n. 4, 307-323, 1951.

Kasischke, E. S.; Melack, J. M.; Dobson, M. C. The use of imaging radars for ecological applications — a review. *Remote sensing of environment*, v. 59, n. 2, 141-156, 1997.

Lee, K. H.; Lunetta, R. S. *Wetland and environmental application of GIS.* 1 ed. New York, USA: Lewis Publisher, 1996. 35p.

Lehner, B.; Doll, P. Development and validation of a global database of lakes, reservoirs and wetlands. *Journal of Hydrology*, v. 296, n. 1-4, 1-22, 2004.

Lopes, S.; Costa, M. T.; Fernández-Llimós, F.; Amante, M. J.; Lopes, P. F. A Bibliometria e a Avaliação da Produção Científica: indicadores e ferramentas. *In: Actas do congresso Nacional de bibliotecários, arquivistas e documentalistas*, n. 11, 7, 2012.

Mao, G.; Liu, X.; Du, H.; Zuo, J.; Wang, L. Way forward for alternative energy research: A bibliometric analysis during 1994–2013. *Renewable and Sustainable Energy Reviews*, v. 48, 276-286, 2015.

Mitch, W. J.; Gosselink, J. G. *Wetlands*. 4 ed. New Jersey, EUA: Published by John Wiley & Sons, 2007. 920p.

Nicholls, R. J. Coastal flooding and wetland loss in the 21st century: Changes under the SRES climate and socio-economic scenarios. *Glob. Environ. Chang*., 14, 69–86, 2004.

Olofsson, P.; Foody, G.; Herold, M.; Stehman; S. V.; Woodcock, C. E.; Wulder, M. A. Good practices for estimating area and assessing accuracy of land change. *Remote Sensing of Environment*, v. 148, 42-57, 2014.

Ottinger, M.; Clauss, K.; Kuenzer, C. Aquaculture: Relevance, distribution, impacts and spatial assessments - A review. *Ocean and Coastal Management*, v. 119, 244-266, 2016.

Ozesmi, S. L.; Bauer, M. E. Satellite remote sensing of wetlands. *Wetlands ecology and management*, v. 10, n. 5, 381-402, 2002.

Paustian, K.; Lehmann, J.; Ogle, S. B; Reay, D.; Robertson, G. P.; Smith, P. Climate-smart soils (Review). *Nature*, v. 532, n. 7597, 49-57, 2016.

Richards, D. R.; Friess, D. A. Rates and drivers of mangrove deforestation in Southeast Asia, 2000-2012. *Proceedings of the National Academy of Sciences of the United States of America*, v. 113, n. 2, 344-349, 2016.

Roth, N. E.; Allan, J. D.; Erickson, D. L. Landscape influences on stream biotic integrity assessed at multiple spatial scales. *Landscape ecology*, v. 11, n. 3, 141-156, 1996.

Tian, B.; Wu, W.; Yang, Z.; Zhou, Y. Drivers, trends, and potential impacts of long-term coastal reclamation in China from 1985 to 2010. *Estuarine, Coastal and Shelf Science*, v. 170, 83-90, 2016.

Van Eck, N. J.; Waltman, L. *In Software VOSviewer*. Centre for Science and Technology Studies. 2019. Disponível em: < https://www.vosviewer.com/>. Acesso em: 3 jan. 2020.

Walker, D. A. *et al.* The circumpolar Arctic vegetation map. *Journal of Vegetation Science*, v. 16, n. 3, 267-282, 2005.

Wang, X.; Zhao, X.; Zhang, Z.; Yi, L.; Zuo, L.; Wen, Q.; Liu, F.; Xu, J.; Hu, S.; Liu, B. Assessment of soil erosion change and its relationships with land use/cover change in China from the end of the 1980s to 2010. *Catena*, v.137, 256-268, 2016.

Wood Júnior, T.; De Medeiros Costa, C.C. Avaliação do impacto da produção científica de programas selecionados de pós-graduação em Administração por meio do índice H. *Revista de Administração*, v. 50, n. 3, 325-337, 2015.

Yuan, F.; Sawaya, K. E.; Loeffelhoz, B. C.; Bauer, M.E. Land cover classification and change analysis of the Twin Cities Metropolitan Area by multitemporal Landsat remote sensing. *Remote sensing of Environment*, v. 98, n. 2-3, 317-328, 2005.

Zhang, P.; Yan, F.; Du, C. A comprehensive analysis of energy management strategies for hybrid electric vehicles based on bibliometrics. *Renewable and Sustainable Energy Reviews*, n.48, 88-104, 2015.

6. ACKNOWLEDGMENTS

The authors would like to thank PGTA/UFMS (the Graduate Program in Environmental Technologies), from the Federal University of Mato Grosso do Sul – UFMS, and PGRN (the Graduate Program in Natural Resources, from the Federal University of Mato Grosso do Sul - UFMS.

This study was carried out with the support of the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES) - Financing Code 88887.494036 / 2020-00;

We also thank CAPES for the access to their Journal Portal.

To PNPD-CAPES for the 2017-2018 Post-Doctorate fellowship granted to Eliane Guaraldo;

To CNPq (National Council for Scientific and Technological Development) for the research productivity fellowship granted to A. C. Paranhos Filho (CNPq Process 305013 / 2018-1).

This research was carried out with support from the Federal University of Mato Grosso do Sul Foundation - UFMS/MEC - Brazil.

Received in: 13/05/2020
Accepted for publication in: 18/11/2020