

China-Brazil Earth Resources Satellite on global scientific literature: trends using scientometric analysis

Satélite Sino-Brasileiro de Recursos Terrestres na literatura científica global: tendências a partir de uma análise cienciométrica

Satélite Chino-Brasileño de Recursos Terrestres en la literatura científica mundial: tendencias de un análisis cienciométrico



Patrick Thomaz de Aquino Martins

Universidade Estadual de Goiás – Formosa – Goiás – Brasil

patrick.tdam@gmail.com



Pedro Paulino Borges

Universidade Estadual de Goiás – Anápolis – Goiás – Brasil

borgespep@gmail.com

Abstract: As a result of the cooperation between Brazil and China, the China-Brazil Earth Resources Satellite (CBERS) is a program for the development of remote sensing satellites which has contributed to the understanding of various phenomena and territorial management. Although there is knowledge production from CBERS data, it has not been characterised within the global scientific literature. Thus, the objective of this study was to evaluate, through a scientometric analysis, the trends and gaps in studies related to the use of CBERS. Considering the ISI Web of Knowledge platform, manuscripts that used or analysed CBERS were searched, resulting in 216 articles, which were examined based on ten different criteria. A significant increase in articles has been observed over time. The CBERS-2 satellite was the most widely used, with CCD being the most frequent of all sensors. When using another remote sensing

product, Landsat and Aqua/Terra satellites (MODIS sensor) were the most observed. A bias related to the nationality of the program maintainers was identified, as well as the prevalence of the English language. The majority of studies took place in terrestrial environments, causing some gaps to be explored. In addition to understanding how the international scientific community has been using CBERS for knowledge generation, the scientometric analysis identified the fulfilment of the purpose for which the program was designed; the autonomy in the generation of orbital data.

Keywords: CBERS. Scientometric. Remote Sensing.

Resumo: Fruto da cooperação entre o Brasil e a China, o CBERS (Satélite Sino-Brasileiro de Recursos Terrestres) é um programa ao desenvolvimento de satélites de sensoriamento remoto o qual tem contribuído ao entendimento de diversos fenômenos e ao gerenciamento territorial. Embora haja produção de conhecimento a partir de dados do programa CBERS, esta ainda não foi caracterizada na literatura científica global. Desse modo, o objetivo do trabalho foi avaliar, por meio de uma análise cienciométrica, as tendências e lacunas dos estudos relacionados ao uso do CBERS. Considerando a base completa da plataforma ISI *Web of Knowledge*, foram pesquisados manuscritos que utilizaram ou analisaram o CBERS, resultando em 216 artigos, os quais foram examinados com base em dez diferentes critérios. Foi observado um aumento significativo de artigos ao longo do tempo. O satélite CBERS-2 foi o mais utilizado, com o CCD sendo o mais frequente dentre os todos os sensores. Quando se empregou outro produto de sensoriamento remoto, os satélites do programa Landsat e os das plataformas Aqua e Terra (sensor MODIS) foram os mais observados. Foi identificado um viés relacionado à nacionalidade dos países mantenedores do programa, assim como a prevalência do idioma inglês. O ambiente terrestre foi onde se deu a maior parte dos estudos, ocasionando algumas lacunas a serem exploradas. Além do entendimento de como a comunidade científica internacional vem utilizando o CBERS à geração de conhecimento, a análise cienciométrica identificou o cumprimento do propósito pelo qual o programa foi concebido, a autonomia na geração de dados orbitais.

Palavras-chave: CBERS. Cienciométrica. Sensoriamento Remoto.

Resumen: Resultado de la cooperación entre Brasil y China, CBERS (Satélite Chino-Brasileño de Recursos Terrestres) es un programa para el desarrollo de satélites de teledetección que ha contribuido a la comprensión de diversos fenómenos y la gestión territorial. Aunque el conocimiento se produce a partir de datos del programa CBERS, todavía esta no se ha caracterizado en la literatura científica global. Por lo tanto, el objetivo de este estudio fue evaluar, mediante un análisis sciométrico, las tendencias y las brechas en los estudios relacionados con el uso de CBERS. Teniendo en cuenta la plataforma ISI *Web of Knowledge*, se realizaron búsquedas en manuscritos que utilizaron o analizaron CBERS, lo que resultó en 216 artículos, que fueron examinados en base a 10 criterios diferentes. Se ha observado un aumento significativo en los artículos con el tiempo. El satélite CBERS-2 fue el más utilizado, siendo CCD el más frecuente entre todos los sensores. Al usar otro producto de teledetección, los satélites Landsat y Aqua/Terra (sensor MODIS) fueron los más observados. Se identificó un sesgo relacionado con la nacionalidad de los encargados del mantenimiento del programa, así como la prevalencia del idioma inglés. El ambiente terrestre fue donde se realizaron la mayoría de los estudios, lo que provocó la exploración de algunas lagunas. Además de comprender cómo la comunidad científica internacional ha estado utilizando CBERS para la generación de conocimiento, el análisis cienciométrico identificó el cumplimiento del propósito para el que se diseñó el programa, la autonomía en la generación de datos orbitales.

Palabras clave: CBERS. Cienciometría. Teledetección.

Introduction

The CBERS (China-Brazil Earth Resources Satellite) is a cooperation program established between the Federative Republic of Brazil and the People's Republic of China, initiated with the signing of a protocol in 1988 for the development of a family of remote sensing satellites to be accomplished jointly by the respective space agencies, the National Institute for Space Research (INPE) and the Chinese Academy of Space Technology (CAST) (LINO *et al.*, 2000).

Agreeing to initially, the development and construction of two remote sensing satellites, which were called CBERS-1 and CBERS-2, the partnership has resulted so far in the construction of six satellites. However, it remains necessary to sign two new agreements; one for the construction of two satellites with more advanced sensors, CBERS-3 and CBERS-4, and another for the launch of a satellite, named CBERS-2B, both of which would fill the time lapse that would exist between the useful life of the first two satellites and the launch of the last two satellites (NOVO, 2010).

While the first three CBERS satellites managed to meet the projected lifetime, the fourth satellite (CBERS-3) was not placed in predicted orbit as a result of a failure in its launch vehicle. Currently, two satellites are in operation, the CBERS-4, which had its early launch due to the aforementioned failure occurred with the CBERS-3, and the CBERS-4A, the result of a new protocol signed between the countries responsible for the program and which has the mission of avoiding or minimizing a new gap in the provision of CBERS images (INPE, 2019).

With characteristics similar to LANDSAT and SPOT satellites (FLORENZANO, 2002; ROCHA, 2007; POWELL *et al.*, 2007), CBERS has been used for various applications related to terrestrial resources, including for the classification and monitoring of crop growth conditions, evaluation of terrestrial resources, monitoring of geological risks and damage and the investigation

and monitoring of ecosystems (YULIANG *et al.*, 2009). In addition to such Earth Sciences applications (which come within the remit of CBERS itself), some studies have focused on the understanding and potentialities of the use of remote sensing techniques (e.g. MARTINS *et al.*, 2009, BENSEBAA *et al.*, 2014; PINTO *et al.*, 2016) or on themes not specifically related to terrestrial resources (e.g. CLARK, 2002, GARCIA *et al.*, 2012; HONG *et al.*, 2006).

This diversity of application, however, has not yet been analysed regarding quantitative aspects, dissemination and use of recorded information, which according to Strehl and Santos (2002), are in the scope of bibliometry and scientometrics. Scientometrics and bibliometry form together with webmetry, the set of fields called informetry. Informetry enables, among other applications, the identification of trends and the growth of knowledge in an area, it can also identify the core journals of a discipline, predict publication trends, study the dispersion and obsolescence of scientific literature, predict the productivity of individual authors, organisations and countries, analyse the processes of citation and co-citation, evaluate the statistical aspects of language, words and phrases, measure the growth of certain areas and the emergence of new themes and detect knowledge gaps on a given subject (VANTI, 2002).

Interdisciplinary in nature, scientometric research has a methodological scope that uses the methods of social, behavioural and natural sciences. Additionally, it makes use of sociological network models, psychological surveys, interviews and the switching of scientific and related fields, in addition to statistics and other mathematical methods (VAN RAAN, 1997). To date, there is no published work that characterises the scientific literature with emphasis on remote sensing, specifically focused on articles published using information from CBERS. Thus, the present manuscript aims to perform a scientometric analysis in the global scientific literature, highlighting the main trends and gaps of studies related to the use of the China-Brazil Earth Resources Satellite.

Material and Methods

From the platform ISI Web of Knowledge (Thomson Reuters Web of Science) were researched, considering all databases, manuscripts that used or analysed the CBERS. For this purpose, articles were sought which contained "China-Brazil Earth Resources Satellite" OR "CBERS*" as part of the title, abstract and/or keywords (topic search). The search was made to collect articles published throughout the period available on the platform (1945 and 2018). The Web of Science was used because it is the most important database in the scientific context, due to the quality, quantity and historical record of indexed journals, in addition to the systematic organisation of information pertinent to scientometric analysis.

For each manuscript, the following information was considered: (a) year of publication; (b) journal; (c) geographic location of the study, by country; (d) geographical coverage (local, regional or continental); (e) the country where the first author's institution is based, attributing to the other authors the character of co-authors, when there were; (f) CBERS satellite (1, 2, 2B, 3 or 4) present in the paper; (g) CBERS sensor used; (h) another remote sensing program (or platform) employed; (i) environment studied (aquatic, atmospheric or terrestrial); and (j) number of citations.

To evaluate whether the number of articles that used the China-Brazil Earth Resources Satellite has increased over time, Pearson's correlation was performed ($p < 0.05$) between the years and the total number of articles published and between the years and the number of articles published in English. Correlations were made using the R program (R CORE TEAM, 2013).

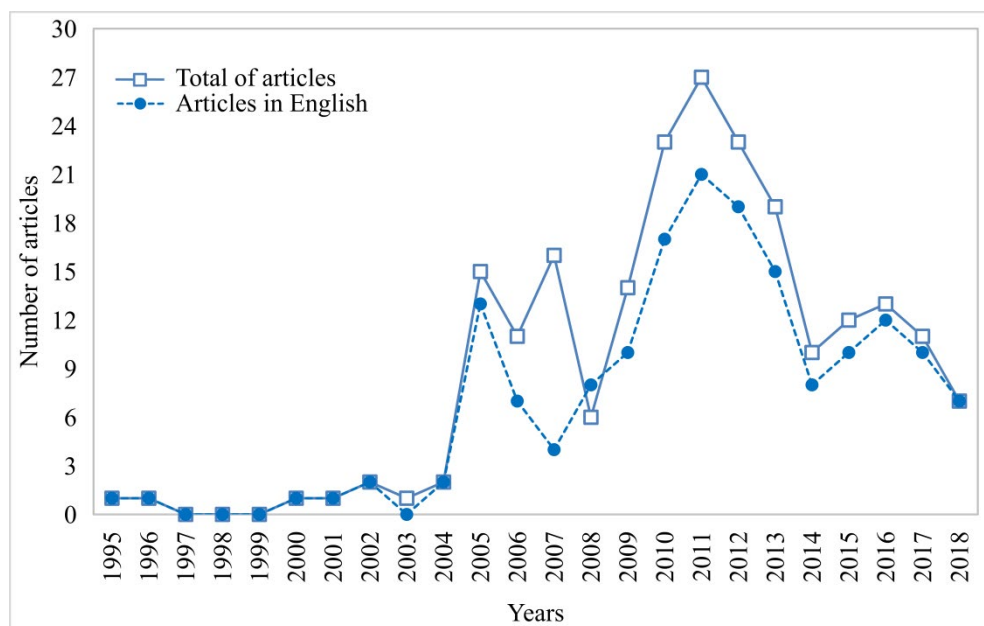
Results

The search returned 231 manuscripts indexed on the ISI Web of Knowledge platform. Of these, 216 were analysed and 15

were discarded for various reasons (articles which only cited the searched-for words, but without in fact, referring to CBERS as part of the content; those not dealing with the China-Brazil Satellite, but another theme with the same acronym; those being part of an unconsidered category, such as the editorial).

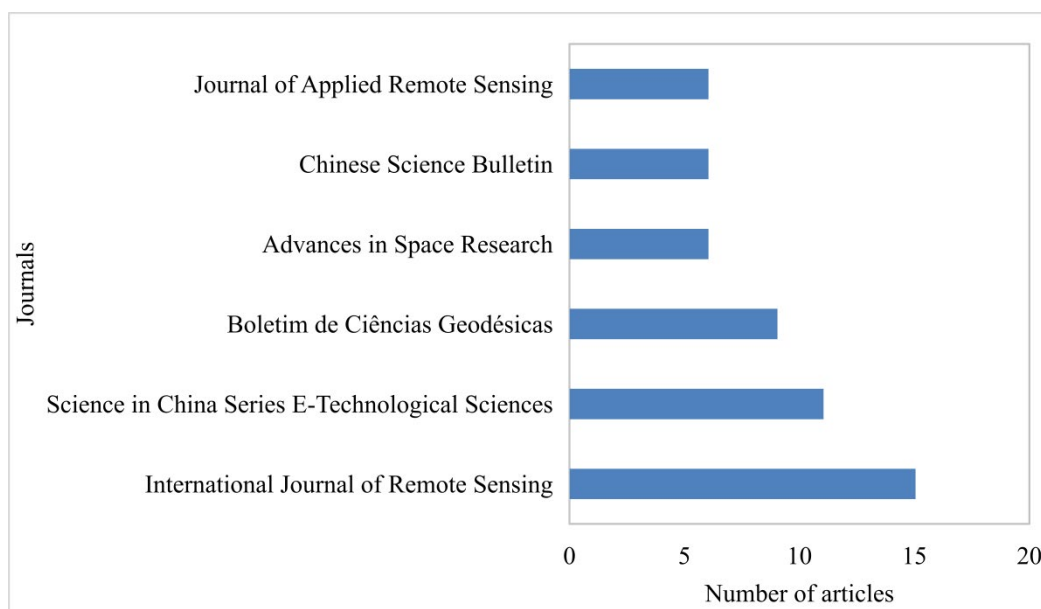
The first manuscript is from 1995, four years before the launch of the first satellite, while the most recent is from 2018, the latest year analysed. On average, 10.3 articles were published per year, with 2011 being the year with the highest number of publications, totalling 26, and 1997, 1998 and 1999 having no published articles (Figure 1). A significant increase in articles over time was observed through correlation ($r = 0.67$; $p < 0.001$), the same pattern of increase in articles was also observed for papers published in English ($r = 0.72$; $p < 0.001$). The most used language in publications was English, with 169 (78.2%) articles, followed by Portuguese, with 32 (14.8%) articles, Chinese, with 9 (4.2%) articles, Spanish, with 5 (2.3%), and Polish, with 1 (0.5%) article.

Figure 1 - Temporal variation in the number of articles published and articles in English that used CBERS and are indexed in the ISI Web of Knowledge between 1995 and 2018.



Articles were identified in 102 different journals, of which about a quarter, 24.5%, are contained in six journals while the International Journal of Remote Sensing was the journal with the largest number of articles (15), followed by Science in China Series E-Technological Sciences, with 11 articles, and Bulletin of Geodesic Sciences, with nine articles (Figure 2).

Figure 2 - Journals with the largest number of articles that used CBERS and are indexed in the ISI Web of Knowledge, between 1995 and 2018.

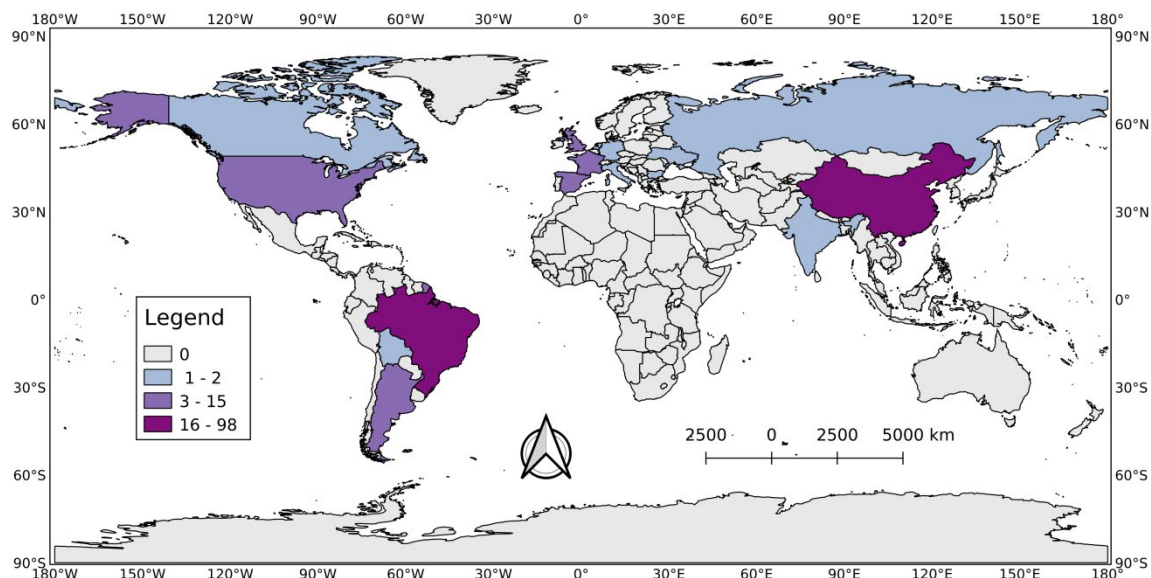


Although there were authors linked to 14 other countries (Germany, Argentina, Bolivia, Bulgaria, Canada, Spain, USA, France, Holland, India, Italy, UK, Russia and Ukraine), most articles (82.3%) was authored by researchers affiliated with institutions in China (44.3%) or in Brazil (38%) (Figure 3).

Regarding the locations studied, a similar pattern is noted, with 43.8% of the articles having China as the location listed for the use of CBERS (considering a single country) and 37.3% for Brazil. There were also articles that had portions of the following nations listed as areas of study: Argentina, Bolivia, Canada, Colombia, Spain, USA,

Thailand and Venezuela. Additionally, work has been carried out in more than one nation and/or in locations in the international public domain, such as Antarctica, space or international waters. It is worth noting that the participation pointed out here only considers articles that made use of some territory for the application of sensor images, ignoring, for example, articles related to pre-launch calibration, satellite attitude, development of welding technology or those identified as an article review.

Figure 3 - Geographic distribution of scientific production that used CBERS and are indexed in the ISI Web of Knowledge, between 1995 and 2018.



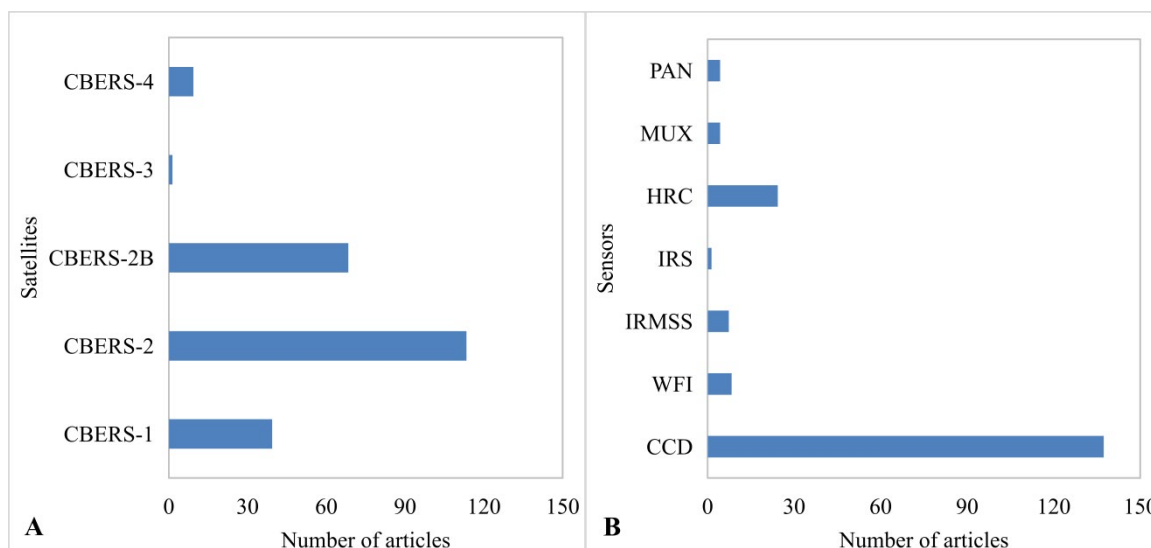
Using the same criterion, it was possible to observe that most studies were conducted within a small geographical area, with a predominance of the local scale in 85.9% of the studies. Only 8.1% of the papers comprised the regional extension and 5.9% the continental scale, with 16.76% of the 216 manuscripts examined not applying to this type of analysis.

In the majority of journals (137), the use of other remote sensing programs, such as Spot, Ikonos, Alos, Geoeye and RapidEye,

was reported, with the occurrence of UAV, aerial photography and videography, as well as non-imagery equipment, such as the spectroradiometer. The Landsat and Terra-Aqua programs (MODIS sensor - Moderate-Resolution Imaging Spectroradiometer) were the programs with the highest occurrence contiguous to CBERS, present, respectively, in 81 and 35 articles, i.e., 59.1% and 25.5% of the manuscripts that made use of another program besides CBERS, or 37.5% and 16.2% of the total studies.

Among the CBERS satellites, the most used was CBERS 2 (49.1%), followed by CBERS 2B (29.5%), CBERS 1 (16.9%) and CBERS 4 (3.9%). With lower participation, CBERS 3 appears, with only one, 0.4%, of the articles (Figure 4A). In relation to the sensors, when it is observed, the CCD is, triggered, the most used, present in 137 articles (74.1%). The other sensors participate with the following percentages: HRC with 13%, WFI with 4.3%, IRMSS with 3.8%, MUX and PAN with 2.2% and IRS with 0.5 (Figure 4B).

Figure 4 - Participation of CBERS satellites (A) and sensors (B) in articles that used CBERS and are indexed in the ISI Web of Knowledge, between 1995 and 2018.



Most of the studies, 101 (70.1%), were developed in the context of the terrestrial environment. In this case, articles where the objective focused on analysing the environment itself (e.g. mapping of forest cover, estimation of crop and susceptibility to mass movement) were counted, as well as articles where the principal element was the development, validation or evaluation of a technique(s) intrinsic to remote sensing, but which were used for or focused on, the terrestrial environment. Meanwhile research involving aquatic and atmospheric environments was much lower, with 36 (25%) and seven (4.9%), respectively.

Regarding the number of times the paper is cited, it was found that 29 (13.4%) of the articles do not yet have any citation, 14 of them were published three years ago or less, while 152 (70.4%) of manuscripts have fewer than ten citations. At the opposite end, the ten most cited articles totalled 1,039 citations, especially the work of Crétaux et al. (2011), the only paper with more than 200 citations (Table 1).

Table 1 - Articles with the participation of the most cited CBERS in the ISI Web of Knowledge database, between 1995 and 2018.

Authors	Title of the paper	Journal	Year	Citations
Cretaux et al.	SOLS: A lake database to monitor in the Near Real Time water level and storage variations from remote sensing data	ADVANCES IN SPACE RESEARCH	2011	214
Ma et al.	China's lakes at present: Number, area and spatial distribution	SCIENCE CHINA-EARTH SCIENCES	2011	127
Pesaresi et al.	A Global Human Settlement Layer From Optical HR/VHR RS Data: Concept and First Results	IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING	2013	119
Shen e Zhang	A MAP-Based Algorithm for Destriping and Inpainting of Remotely Sensed Images	IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING	2009	118
Du et al.	Assessing the effects of urbanization on annual runoff and flood events using an integrated hydrological modeling system for Qinhuai River basin, China	JOURNAL OF HYDROLOGY	2012	113

(continue)

Niu et al.	Mapping wetland changes in China between 1978 and 2008	CHINESE SCIENCE BULLETIN	2012	101
Liu et al.	Evolving neural network using real coded genetic algorithm (GA) for multispectral image classification	FUTURE GENERATION COMPUTER SYSTEMS	2004	73
le Maire et al.	Leaf area index estimation with MODIS reflectance time series and model inversion during full rotations of Eucalyptus plantations	REMOTE SENSING OF ENVIRONMENT	2011	59
Chuvieco et al.	Global burned-land estimation in Latin America using modis composite data	ECOLOGICAL APPLICATIONS	2008	58
Romero-Ruiz et al.	Landscape transformations in savannas of northern South America: Land use/cover changes since 1987 in the Llanos Orientales of Colombia	APPLIED GEOGRAPHY	2012	57

Discussion

The objective of the current study was to evaluate the main trends and gaps of research related to the use of the China-Brazil Earth Resources Satellite (CERBS). It was observed that the number of articles on the subject has increased significantly over time. The increase in the number of papers with CBERS corroborates the global trend in the use of remote sensing in scientific studies, as identified by Vijaylakshmi and Ambuja (2013), Zhuang *et al.* (2013) and Hanqing *et al.* (2016). This certainly accompanies the growth of production in the scientific literature as a whole, as research in several areas (e.g. BORGES *et al.*, 2015; COSTA *et al.*, 2018) have seen an increase in the number of publications over the years.

A little over a decade ago Powell *et al.* (2007) indicated that documented applications of CBERS images were difficult to find in the primary literature. Although this picture has improved, as can be noted in the present work, some fundamental procedures to more advanced uses of images, such as atmospheric correction, have not yet been widely parameterised/modelled for CBERS images. The occurrence of articles regarding CBERS in some reference journals, such as within the International Journal of Remote Sensing, which

recorded the largest number of articles that used CBERS, can assist in the dissemination of the uses and potential of CBERS images, providing the possibility of developing techniques and applications not yet tested in CBERS images.

Despite being a traditional journal in this area of research, the number of issues published annually by the International Journal of Remote Sensing, totalling 24 since 2002, appears to influence the position of dominance achieved by this journal regarding the presence of papers with CBERS. It is also worth mentioning that, among the six journals with the largest number of articles, half are journals edited or belonging to organisations based in China or Brazil, demonstrating a bias that may be associated with the countries that maintain the satellite program.

The predominance of the English language as the most used in the articles, as well as the increase of articles published in English over the time analysed, is justified by the fact that, besides being a *lingua franca* of science (MENEHINI; PACKER, 2007), in this language, the research becomes accessible to a larger audience, resulting in a greater number of citations (BITETTI; FERRERAS, 2017). The use of Portuguese and Chinese is clearly associated with the authors' native language, concomitant with the nationality of the journal indexed in the evaluated database.

It's frequent presence in the top two in several surveys related to the production of papers (e.g. THOMSON REUTERS, 2012; SCIMAGO, 2007), including research related to remote sensing (ZHUANG *et al.*, 2013; SARRAGIOTTO; BENEDITO, 2013) highlights China's unsurprising position as the largest contributor to scientific work addressing CBERS. Brazil's position, however, confirms the trend among natural or settled researchers in one of the CBERS' developing countries to use information about this program in scientific papers. Since the collection of terrestrial reference data *in situ* is an intrinsic part of the Remote Sensing process (JENSEN, 2009), and that there is a predominance of authors from China and Brazil, it is reasonable that most studies take place in the territories

of these countries, especially considering the reduction of costs to obtain the data.

The same line of understanding can be attributed to the high number of articles of local scope. In this scale of analysis, identified here as works whose geographical scale has approached areas equal to or smaller than a state or province, despite the territorial extent of the countries with higher production of studies with CBERS, the costs to perform the *in situ* stages are greatly reduced, when compared to studies on regional (states or countries) or continental scales (countries and planet), mainly in experimental work.

Attempts to understand the potential of CBERS images to different remote sensing data applications partly explain the use of data from other remote sensing programs. This approach is common in experimental analyses, where researchers seek to test the applicability of images to certain studies, or techniques, using other images as a reference (e.g. ZHANG, TANG; DONG, 2010; DU *et al.*, 2012; TAO *et al.*, 2013; BOGGIONE *et al.*, 2014). As the articles being analysed are contained in a database that stands out for its association with international relevance, it is expected that most of the research will be based on consolidated programs.

One of the justifications for the use of CBERS concomitant with other sensors/programs is the ability to complement missing characteristics in one of the images, such as those associated with resolutions (spatial, spectral or temporal). The preference for the Landsat program is explained not only by the similarity already mentioned between CBERS and Landsat, but also because it is among the most widely used satellites as a source of data in several types of studies, such as those related to water resources (FEYISA *et al.*, 2014), land cover (KNORN *et al.*, 2009) and surface temperature (LIU; ZHANG, 2011), which is justified by the nearly five decades in which Landsat images have been put to the test in different areas of knowledge.

Not as long-lived as Landsat, but providing data since 2000, the satellites Terra and Aqua, equipped with the MODIS sensor, are noted for providing data with a revisit time of between one and two days, besides being rigorously validated and widely used in many applications (GAO *et al.*, 2015). Satelitarian data with high temporal resolution, such as MODIS, are always associated with images with low spatial resolution (WU *et al.*, 2016), which explains the use of CBERS images with those from MODIS.

The relative equivalence of the CCD sensor, present in the first three satellites of the Sino-Brazilian program, with the Thematic Mapper (TM) and the Enhanced Thematic Mapper Plus (ETM+), of the Landsat satellite series, clarifies the presence of this sensor as the most used CBERS. Added to this similarity is the fact that the spatial resolution of these sensors is intended to provide adequate scale for a wide variety of terrestrial resource applications (ROGAN; CHEN, 2004).

Like Landsat, CCD images have been used for various purposes, such as the analysis of land use and coverage (ZHENG *et al.*, 2012; WANG *et al.*, 2012), evaluation of flood events (MENDONÇA *et al.*, 2012), estimates of cultivated areas (LI *et al.*, 2011) and suspended matter concentration (ZHANG *et al.*, 2010). The wide predilection for CCD sensor images, associated with the lifetime, reflects and justifies the position of the second satellite in the series, the CBERS-2, as the most recurrent among the analysed studies.

The propensity for the application of CBERS to the terrestrial environment may be related to the diversity of the application areas that use remote sensing to produce knowledge in this environment. These may include agriculture, geology, forestry and urban studies, in addition to cross-cutting themes eminently linked to this environment, such as fire and land use, plurality that is not possible to aquatic and atmospheric environments. Although not the environment with the greatest application of CBERS, the aquatic environment stands out as the main environment among the articles that received the highest number of citations (top 10),

with four of the six articles with more than 100 citations, and the only one with more than 200 citations.

Regarding citations, the information contained in Table 1 reflects some patterns already known in bibliometry. Articles with more than four authors, for example, tend to receive more citations than the average (HSU; HUANG, 2011), as is the case with nine of the ten articles with more than 100 citations. In all articles the language used was English, which, as already reported, is also associated with a greater number of citations (BITETTI; FERRERAS, 2017). Even though it is the second country with the highest presence of authors and local studies, no research whose authorship or locality is Brazilian is among the 10 most cited articles (all in Table 1), corroborating what Meneghini *et al.* (2008) identified; that articles in prestigious journals with Brazilian authors, as well as other Latin American nationalities, receive fewer citations. For example, in the present study, the first article of Brazilian authorship is only in the 30th position. In addition to the information contained in Table 1, it was also possible to observe the low level or absence of citations of most articles, a paradigm also already identified in the scientific community (COLQUHOUN, 2003).

Final consideration

Being linked to one of the countries maintaining the CBERS program seems to influence the use of satellites and images in studies published in quality journals recognised by the Web of Science, since China and Brazil monopolised the variables related to nationality. The maintenance of growth in the use of English as a language of publication tends to make CBERS better known within the international scientific sphere literature, providing opportunities for the development of techniques and the exploration of applications not yet contemplated or unconsolidated, to the images and satellites of the program.

With regard to terrestrial resources, for example, the little attention paid to aquatic and atmospheric environments can be considered a gap, which should be explored, in the application of CBERS to these environments. Attention should be focussed especially in terms of citation (which the research carried out in the aquatic environments demonstrated) and the contemporary relevance, in academia, of themes related to climate change.

The scientometrics has developed the understanding of how CBERS has been used to produce scientific knowledge in mediums of high academic prestige. The scenario identified here is likely to remain the same in the coming years, since although CBERS images can be considered equivalent in terms of quality, characteristics and cost to the user, for remote sensing programs and missions widely used in the international scientific community, such as Landsat and Sentinel, they lack a unique quality (e.g. making images available in surface reflectance values or a product resulting from spectral index) which would place them in a truly competitive position with their peers. If, on the one hand, this situation can denote the low use of CBERS by the international scientific community, on the other it ratifies the investment made by Brasil and China in search of independence in the generation of satelitarian data and in the pursuit of significant emancipation in various areas, such as technological, geopolitical and environmental.

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Declaração de contribuição individual

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Patrick Thomaz de Aquino Martins – Currently Professor at the State University of Goiás. Graduated in Geography from the State University of Santa Cruz, Master in Geography from the Federal University of Sergipe and PhD in Geosciences and Environment from the São Paulo State University. ORCID <http://orcid.org/0000-0003-3814-3982>

Pedro Paulino Borges – Graduate in Biology and Master in Natural Resources and currently Ph.D. student at the State University of Goiás. ORCID <http://orcid.org/0000-0003-2173-4276>

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