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Scientometric diagnosis of the use of remote sensing images in Landscape Ecology studies

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ABSTRACT. This work analyzed the implementation of images from the remote sensors ASTER, CBERS, IKONOS, LANDSAT, MODIS, NOAA, QUICKBIRD and SPOT in Brazilian and international Landscape Ecology studies, developed between 1991 and July 2009. The study analyzed works published in article form using the *ISI Web of Knowledge* website, and theses and dissertations from the “Thesis Database” at CAPES (*Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior*). A total of 124 Brazilian and 144 international published works were examined, analyzing 11 and six parameters, respectively. It was observed that the images from sensors MODIS (53%) and LANDSAT (32%) are employed more frequently in international research studies, whereas in Brazil there is preference for products from LANDSAT (65%) and SPOT (11%). The interval with the highest scientific output occurred between 1999 and 2009 (95%) in Brazil and from 1997 to 2009 (93%) internationally, while 2008 was the most significant year for both assessments, accounting for 19 and 18% of published works, respectively. The intense use of satellite imagery in Landscape Ecology studies observed in the last decade indicates there will be an increase in this technology in landscape analysis in coming years.

Keywords: remote sensing, database, scientometrics, LANDSAT, SPOT, MODIS.

Diagnóstico cienciométrico do uso de imagens de sensores remotos em estudos de Ecologia de Paisagens

RESUMO. Este trabalho analisou a implementação das imagens dos sensores remotos ASTER, CBERS, IKONOS, LANDSAT, MODIS, NOAA, QUICKBIRD e SPOT nos estudos nacionais e internacionais de Ecologia de Paisagem, desenvolvidos entre 1991 e julho de 2009. Foram examinadas publicações em forma de artigos, teses e dissertações, com o auxílio do sítio *ISI Web of Knowledge* para os primeiros do “Banco de Teses” da Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior (Capes) para os demais. Foram examinadas 124 publicações nacionais e 144 internacionais, com a análise de 11 e seis parâmetros, respectivamente. Constatou-se que as imagens dos sensores MODIS (53%) e LANDSAT (32%) são mais empregadas em pesquisas internacionais, enquanto no Brasil há preferência pelos produtos do LANDSAT (65%) e do SPOT (11%). O maior intervalo de produção científica ocorreu entre 1999 e 2009 (95%) no Brasil e entre 1997 a 2009 (93%) no exterior, enquanto o ano de 2008 foi o mais significativo para ambos os levantamentos, com índices de publicação de 19 e 18%, respectivamente. A intensa utilização de imagens de satélite em estudos de Ecologia de Paisagem verificada na última década suscita que haverá incremento crescente desta tecnologia nas análises da paisagem nos próximos anos.

Palavras-chave: imagem de satélite, base de dados, ciencimetria, LANDSAT, SPOT, MODIS.

Introduction

Remote sensing imagery constitutes an adequate technological support tool in scientific research studies, especially for the broad range of spatial scales available to detect targets on the Earth's surface. This characteristic makes it an appropriate tool in studies ranging from small-scale projects involving homogenous patches up to extended heterogeneous zones (FRANKLIN; FORMAN, 1987). Another potential use of this tool is in the imaging of a single area of interest at short-interval

temporal repetitions. This is applied in the tracking of variations in temporal evolution of a single area by observing seasonal, anthropic and atypical changes, considering one or more variables with regard to a phenomenon. This latter concern is reflected on studies of natural disaster patterns (BRAGA et al., 2006), pesticide issues (GHINI et al., 2007; HAMADA et al., 2006), health problems (ESTRADA-PEÑA; VENZAL, 2007), the dynamics of total organic carbon in the soil (LOPES et al., 2008) and primary production (SVORAY et al.,

2008) with regard to the new climate conditions resulting from the rise in global temperature on the atmosphere. In addition to broad spatial and temporal scales, satellite images fit into Landscape Ecology studies for their holistic view of the study objects, making possible a systemic approach.

The dissemination of Landscape Ecology studies intensified starting in the 1980s (FORMAN, 1995), a period that coincided with the significant development of spatial analyses (WU; HOBBS, 2002). A key point for the increase in research studies in the field with the use of satellite imagery was the launch of several sensors transported in satellites: LANDSAT (1972), NOAA (1978), SPOT (1986) and ASTER (1999), CBERS (1999), IKONOS (1999), MODIS (1999) and QUICKBIRD (1999) (JENSEN, 1999). This variety in equipment for generating imaging of the Earth's surface facilitated the interpretation of the influence that landscape configuration has on ecological processes and patterns (METZGER, 2001).

From this knowledge, the global view afforded by remote sensing images has become an important tool in choosing action strategies regarding the conservation and protection of ecosystems. Thus, images from the many different remote sensors should be increasingly used in landscape ecology studies, with the purpose of contributing to territorial planning decisions that are compatible with ecological needs, supporting the global well-being of human and natural populations.

The objective of this work was to systematically investigate the use of satellite imagery captured by eight different remote sensors in Brazilian and international landscape ecology research studies, over a 19-year interval.

Material and methods

The study analyzed 268 works selected between July 13-15 2009, of which 144 were accessed using the "General Search" routine of the *ISI Web of Knowledge* website (ISI, 2009) and 124 by accessing the "Thesis Database" at CAPES (*Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior*) (CAPES, 2009). International works were selected by using the keyword "landscape ecology" in conjunction with the words "ASTER", "CBERS", "IKONOS", "LANDSAT", "MODIS", "NOAA", "QUICKBIRD" and "SPOT", individually and present in the title, abstract or keywords. For analysis, the following data were selected: a) publication year; b) country of origin of the main author; c) document type; d) indexed periodical; e) number of citations; f) impact factor (IF) of the three most cited periodicals and the three articles with the

most citations; g) document type of the three most cited records; h) knowledge area; and i) publication language. For the study of Brazilian works, keywords were also related to the name of each remote imaging sensor individually, in conjunction with the term "*ecologia de paisagens*" ("landscape ecology"). The following data were collected from each work: a) document type (dissertation or thesis); b) graduate program field; c) field of study; d) institution; e) support agency; and f) publication year.

Results and discussion

International works

The most used images came from sensors LANDSAT (65%), SPOT (11%), MODIS (6%) and IKONOS (6%). The most frequent document types were articles (83%), annals (11%) and reviews (5%). With regard to knowledge area, all works were categorized as Science and Technology; however, only 21% belonged to the Social Sciences. The remaining fields did not show significant levels. The English language was predominant among the analyzed works (97%), while Spanish (1%) and French (1%) made up a small fraction. The country of origin of the main author showed fewer discrepancies, comprising 28 countries, with highlights to the United States (47%), China (7%) and England (5%). Publication years ranged from 1991 to 2009; however, 93% of works were published between 1997 and 2009, and the years with the most published works were 2008 (18%), 2006 (10%) and 2004 (9%). There were a total of 2,077 citations for all works combined, which was more than 14 times the number of works produced. The most cited articles used sensors LANDSAT (81%), NOAA (5%) and IKONOS (5%). Indexing took place in a total of 67 different periodicals, the most frequent being *Landscape ecology* (11%), *International Journal of Remote Sensing* (8%) and *Remote Sensing of Environment* (6%), which are journals with Impact Factors (IF) of 2.061, 1.041 and 3.013, respectively. The most cited works were published in the *Journal of Vegetation Science* (FI: 2.251), *Ecology* (FI: 4.822) and *Freshwater Biology* (FI: 2.650), being two articles and one review, respectively. The most frequent among the 12 main sub-categories were Ecology and Environmental Sciences (26%), Biodiversity and Conservation (15%) and Science and Technology (15%).

Brazilian works

The study evaluated 124 works, including dissertations (69%) and theses (31%) produced between 1995 and 2008, distributed among 46 graduate programs, with prevalence of the fields of Ecology (23%), Geography (21%) and Remote Sensing (5%).

Among the 26 areas of study found in the works, the main were ecology (31%), geography (19%) and remote sensing (8%). The works were developed at 33 higher education institutions, the most frequent being the Federal University of São Carlos (10.5%), University of Brasília (9.7%), and Universidade Paulista Júlio Mesquita Filho (9.7%). A division by state of the works produced showed a predominance of São Paulo (36%) and Paraná State (10%), in addition to including the Federal District (10%), among the 16 states found in the survey. Only 86 of the published works mentioned support agencies; the most cited were CAPES (43%), *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq) (26%) and *Fundação de Amparo à Pesquisa do Estado de São Paulo* (Fapesp) (9%). The most often used images in Landscape Ecology studies were those detected by sensors MODIS (53%), LANDSAT (32%) and SPOT (6%), and the most prolific years in terms of publishing were 2008 (19%), 2007 (12%) and 2001 (12%). The 1999-2009 time period showed the highest number of works, comprising 95% of the total.

These results demonstrated there are more works indexed in periodicals (55%) than found in dissertation (35%) and thesis (15%) format during the study period, which is understandable given the longer time required to develop the latter two, particularly theses.

In international works, Remote Sensing images came preferentially from sensors LANDSAT and SPOT, whereas in Brazil MODIS and LANDSAT are the most used (Figure 1). However, an increase is expected in the use of LANDSAT images for Brazilian research studies in the next few years, as the images have been available free of charge from the National Institute for Space Research (INPE) since January 2008.

The higher frequency of international works published in article form had been previously observed by other authors (GUIMARÃES; PINTO, 2005; KOPP et al., 2007; LOLIS et al., 2009), and is due to the fact that this format is read more often than the others (KING; TENOPIR, 1998).

This favors the scientific visibility of research studies, resulting from wide exposure and accessibility to the results and by the greater chance of retrieval, reading and citation (PIZZANI et al., 2008). Another predominance observed in the international assessment is of English-language publishing, which, like the previously mentioned factor, increases the chance of the work being read by the scientific community and results in global exposure of its results (BICAS, 2000; MEIRELLES; BONAMIGO, 2003; VIEIRA, 2005). Moreover, any article published in English and included in a

journal indexed in an international database will not be read only by those who are not interested or are prejudiced (PINTO; ANDRADE, 1999).

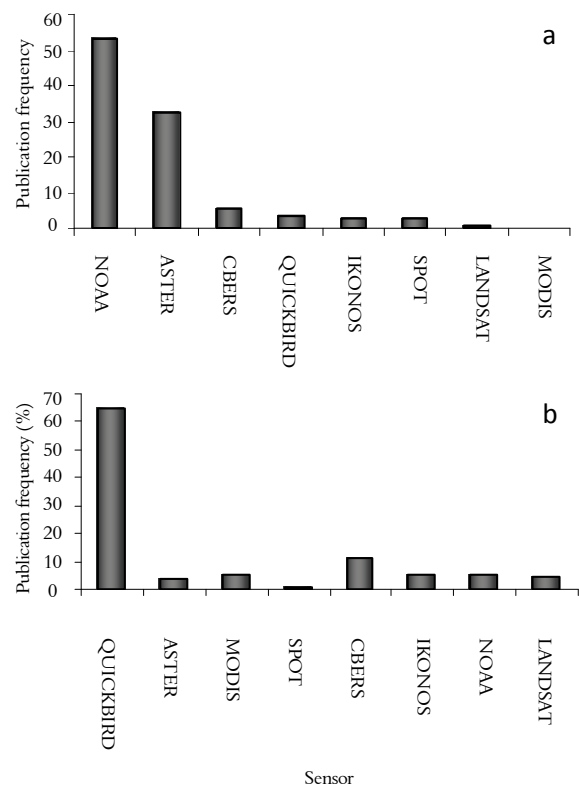


Figure 1. Frequency distribution (%) of publishing of domestic (a) and international (b) Landscape Ecology works that made use of images from different remote sensors.

Contrary to these discrepancies, the country of origin of the first authors of articles showed great diversification (Figure 2), which demonstrates the worldwide dissemination of Remote Sensing technology.

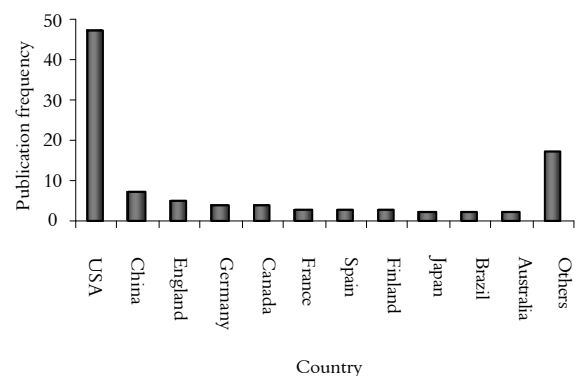


Figure 2. Publishing frequency (%) by country of origin of the first author.

Among the countries that stood out in the use of this tool, China's participation was surprising, as it

this is seldom observed in other scientometric works. Even so, the high frequency of American and English authors is common (Figure 2), and has been a common pattern in other quantitative analyses of scientific production (GUIMARÃES; PINTO, 2005; PIZZANI et al., 2008). The repeated results are closely related to the high production capacity and technological innovation by these countries (PIZZANI et al., 2008) and the fact that most indexed periodicals in the database are from the United States (KOPP et al., 2007). The most cited works were published in journals with high impact factors, which may explain the high global value of the citations of these works. Some authors highlight a reduction in scientific leaderships in several areas, causing lower demand for low-impact factor journals, resulting in a distorted picture that “all that is good in science is restricted to high impact factor journals” (PINTO; ANDRADE, 1999).

With regard to publishing year, international works preceded Brazilian publications by only four years. Brazilian works were produced almost entirely in the last ten years and have shown great progress, especially considering that data from 2009 had not yet been included in the analyzed database during the study period (Figure 3).

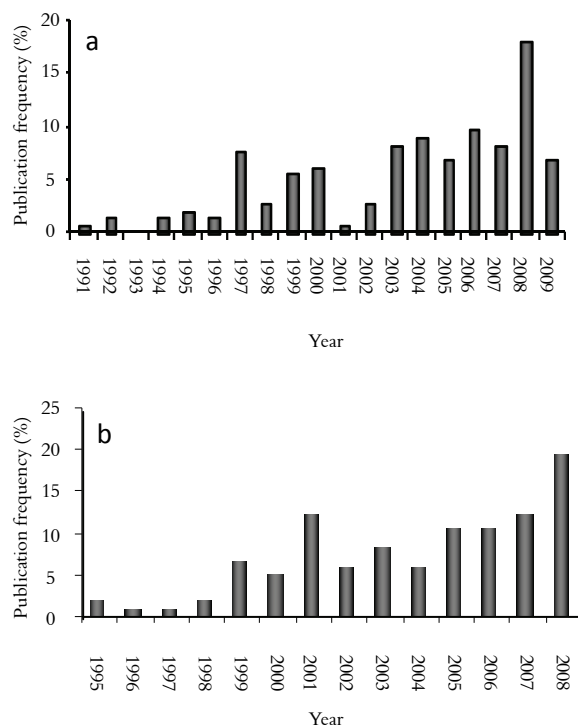


Figure 3. Frequency distribution (%) of publishing of international (a) and domestic (b) works, by year.

The high number of published works in 2008 in both assessments (Figure 3) increases the expectation with regard to a progressive increase in works that employ this technology in landscape analyses. The main application fields of the dissertations and theses are in accordance with these expectations, especially through the high participation of the Ecology area fields (Table 1).

Table 1. Frequency distribution of domestic published works (%) according to field of study.

| Field | % |
|---|----|
| Ecology | 31 |
| Geography | 19 |
| Remote Sensing | 8 |
| Conservation | 7 |
| Biology | 4 |
| Interdisciplinary | 4 |
| Forestry Resources and Forest Engineering | 4 |
| Planning | 3 |
| Agronomy | 2 |
| Agrarian Sciences | 2 |
| Civil Engineering | 2 |
| Geology | 2 |
| Multidisciplinary | 2 |
| Others | 12 |

The high number of higher education institutions found in the domestic publishing assessment (Figure 4) showed there is vast knowledge in Brazil of the technological support provided by Remote Sensing in Landscape Ecology research studies.

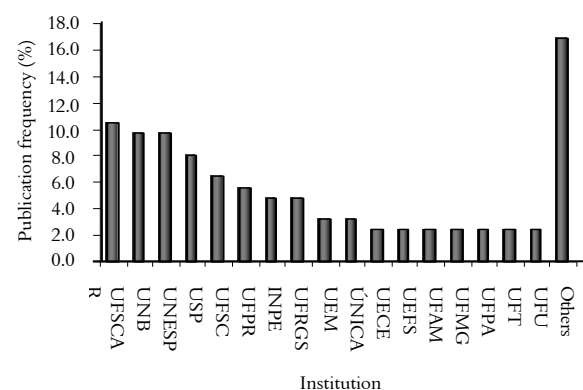


Figure 4. Frequency distribution (%) of publication by Brazilian higher education institutions.

Moreover, it was observed that, in spite of Brazil's vast expanses, there is wide dissemination of knowledge throughout the country, as shown by the participation of several different states in published scientific works that implement satellite imagery technology (Figure 5).

The predominance of works from São Paulo State was expected, as it is a heavily populated region hosting a large number of renowned institutions of higher education. On the other hand, Fapesp was

not the most cited support agency in the works, which indicates the need for greater investment in this research field by the institution (Figure 6).

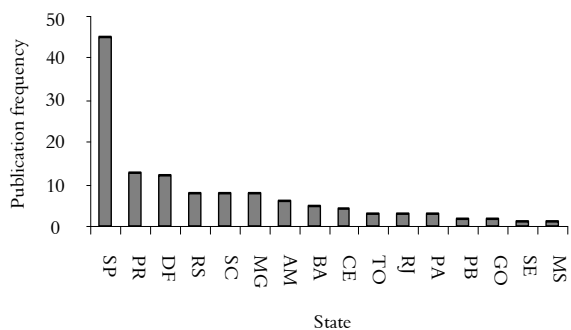


Figure 5. Frequency distribution (%) of Brazilian published works by state.

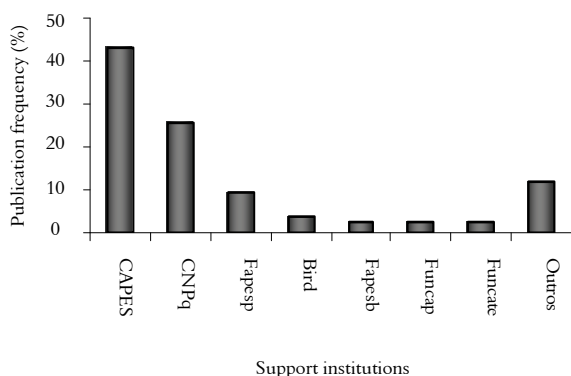


Figure 6. Frequency distribution (%) of Brazilian published works financed by support institutions.

Conclusion

Remote Sensor images used on Landscape Ecology studies was predominantly from MODIS and LANDSAT sensors internationally, and from LANSAT and SPOT sensors in Brazil. The number of domestic and international published works was similar, with predominance of articles, in English language, and by first authors from the United States in the international assessment. In Brazil, the dominance belonged to works published in São Paulo State, by the Federal University of São Carlos, and financed by CAPES. The progressive number of published works using the sensors images in Landscape Ecology researches indicate increase in its technique application in Brazil and internationally.

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