CAN WE MEASURE A REMOTE SENSING SCIENCE? BIBLIOMETRIC ANALYSIS OF THE LITERATURE, 1975-2005

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ABSTRACT: Remote sensing science is a rapidly growing field of Earth sciences. Since emergence and to present day, an extensive literature has evolved which traces the wide application of remote sensing in human activities. According to the ISI Web of Science in the 1975-2005 time span more then 20,000 papers were published on remote sensing. The number of papers grew exponentially with doubling period of about 6 years. Notwithstanding all specialized journals, there is a lot more remote sensing papers published in a vast list of source titles (up to 350 journals). Only 25% of retrieved papers are published in 10 journals which ISI assigns to subject category of remote sensing. In 2005 all these journals published 1291 articles and received *cca* 24,000 citations. Average impact factor of the journals is equal to 1.181 and average cited half-life is 7.1. It means that an average paper in remote sensing journals is cited more then once per year and half of citations the paper receive within the next 7 years after publication. The time line of remote sensing periodicals issued in 1927-1995 shows an exponential growth with doubling period about 15 years. After 1995 there is a prominent deviation from the exponential curve which shows the demand saturation for specialized journals. The features revealed are discussed in terms of dynamics and impact of remote sensing in current Earth sciences development.

KEY WORDS: Remote sensing literature, Bibliometrics, Scientometrics, Earth sciences

1. INTRODUCTION

In the broad sense remote sensing means the acquisition of physical data of an object by a device separated from it by some distance. In the scope of this paper we have used definition of remote sensing as "the practice of deriving information about the earth's land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the earth's surface" (Campbell, 2002).

However much has been learned in the past 50 years, it would be misleading to suggest that remote sensing is a young science. The term "remote sensing" was coined the mid-1950's by Evelyn L. Pruitt, a geographer formerly with the Office of Naval Research (Short, 2006). The history of remote sensing, however, is considerably older. As early as 1840, balloon photography was used for topographic surveying. Kites were used to obtain aerial photographs from about 1882. The airborne camera was developed for aircraft since 1909 (Campbell, 2002). But expansion of space exploration in the 1960's gave new opportunities for remote sensing. At the beginning of 1970s the first remote-sensing satellites were launched in the United States (Landsat 1) and in the USSR (Meteor), in 1986 France launched the first of its SPOT remote-sensing satellites (Space exploration, 2006). Satellite remote sensing quickly evolved from the sphere of pure research to that of worldwide day-to-day application. Now remote sensing applications are still developing quickly, with many books and scientific papers published each year.

So the remote sensing science is a rapidly growing field of Earth sciences. Since emergence and to present day, an extensive literature has evolved which traces the wide application of remote sensing in human activities. The aim of this report is to discuss in terms of dynamics and impact of remote sensing in current Earth sciences development.

2. DATA ACQUISITION AND PROCESSING

The main bibliographic database used in the study was Thomson-ISI Web of Science service available on URL http://portal.isiknowledge.com. Searches were performed using "remote sensing" key word in SCI-EXPANDED database in the 1975-2005 time span. More then 20,000 papers was published in a given time in ISI-covered scientific journals worldwide.

For estimations of numbers of book published or journals issued on remote sensing the EBSCO Book Index with Reviews on URL http://search.ebscohost.com and Ulrich's Periodicals Directory on URL http://www.ulrichsweb.com and were used, respectively. Data retrieval was performed in these databases with "remote sensing" key word. More then 800 books and 52 currently issued journals were found in those databases.

To calculate the growth rates of the literature the semi-logarithmic plot of cumulated numbers of the books or papers published during period of 1975-2005 were used. Assuming exponential growth of those data is correct, we may calculate the doubling periods D by the slopes of the linear trends (Figures 2 and 3).

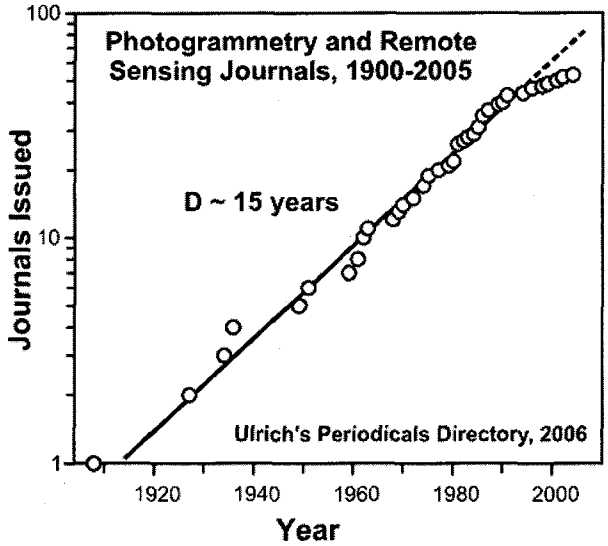

Figure 1. Growth of photogrammetry and remote sensing journals, 1900-2005. Data from the Ulrich's Periodicals Directory, 2006.

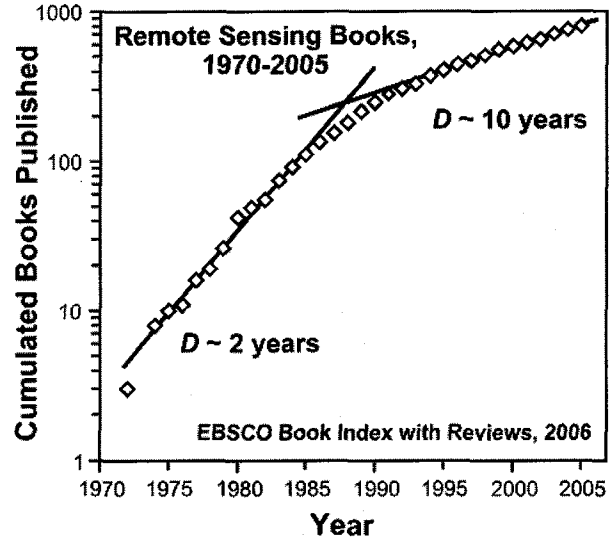

Figure 2. Growth of remote sensing books, 1970-2005. Data from EBSCO Book Index with Reviews, 2006.

3. RESULTS AND DISCUSSION

According to Derėk Price (Price, 1963) to measure a progress of science or some scientific discipline one can evaluate the number of people involved or their scientific outputs (books, journals, papers, patents *etc.*) as well as material inputs (for example, Domestic Expenditure on Research and Experimental Development or university monetary funds). In remote sensing science we have tried to estimate growth of scientific outputs as dynamics of periodicals issued, books published and scientific papers appeared in Thomson-ISI journals.

3.1 Exponential Growth of Remote Sensing

Figure 1 depicts the growth of photogrammetry and remote sensing journals published since 1900. Through 1995 this growth was exponential with doubling period D of *cca* 15 years. Last decade noticeable decrease of number of newly issued journals is observed. It seems reasonable to say that the pool of remote sensing specialized journals has been reached the saturation.

In accordance with this picture the number of remote sensing books (Figure 2) increases in two ways: before 1985 growth is outlined by doubling period $D \sim 2$ years and after 1990 number of books increases exponentially with $D \sim 10$ years. This growth rate remains the same to present day. It means that in remote sensing books are in constant requisition last 15 years and in the next 10 years more then 800 books will be published.

The search in the Thomson-ISI Web of Science database (SCI-EXPANDED) revealed exponential growth of scientific papers published in ISI-covered journals in the 1975-2005 time span (Figure 3). Doubling period of this increase is 5.81 years. This growth rate is one of the highest known for Earth sciences literature and it is similar in size to those in biomedical publications.

So in the next six years more 20,000 papers will be published on remote sensing worldwide. Is remote sensing community ready for this scientific information boom?

3.2 Diffusion of Remote Sensing Knowledge

Analysis of remote sensing papers retrieved in ISI bibliographic database showed wide spreading of the papers between scientific periodicals and disciplines. Notwithstanding all specialized journals, there is a lot more remote sensing papers published in a vast list of source titles (up to 350 journals). Only 25% of retrieved papers are published in 10 journals which ISI assigns to subject category of remote sensing.

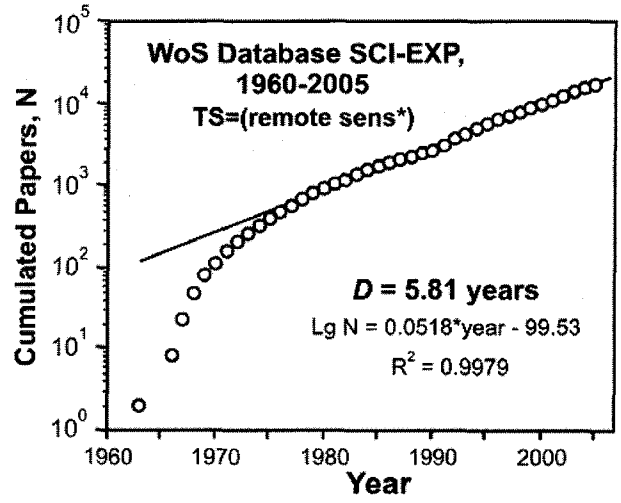

Figure 3. Growth of remote sensing papers, 1960-2005. Data from Thomson-ISI Web of Science database (SCI-EXP, 1960-2006).

In the 1975-2005 time span there is prominent increase the remote sensing applications in ecology and environmental sciences, meteorology and oceanography (Figure 4). On the other hand the trend is toward decrease of share of publications in geochemistry and geophysics as well as in optics and imaging science. Other remote sensing applications account for 30-50% of papers published in 1975-2005 (Figure 4). Those features trace the wide application of remote sensing in human activities.

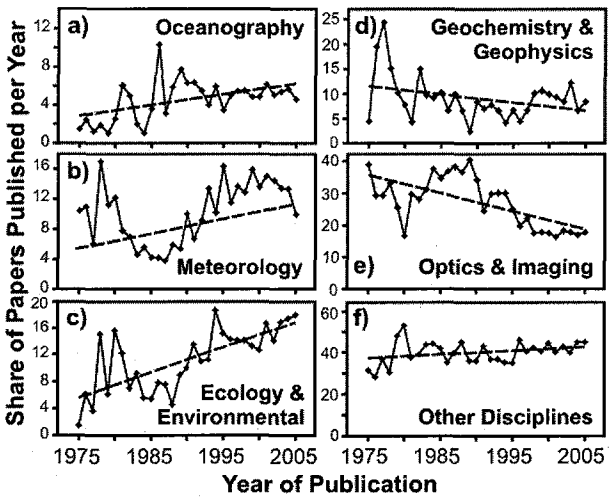

Figure 4. Shares of some disciplines in remote sensing papers, 1975-2005. Data from ISI SCI-Expanded database.

3.4 Citation Delay in Remote Sensing Science

The growth rates of scientific publications in remote sensing show some different values: for books doubling period ***D*** was 2 years at the beginning of satellite era (1970-1980s) and after that doubling period was 10 years. The growth of periodical literature was practically constant in 1975-2005 and ***D*** was equal to ~6 years.

How does scientific literature in remote sensing used? To answer a question we analyzed reference lists in all papers of remote sensing journals published in 2005. Figure 6 shows this citation delay curve. Obviously the citation curve has two regions: first one, 1955-2005 of "current" literature with delay half-life of 6.2 years and second, 1820-1955 of "classic" (Price, 1965) citations with delay of 20 years. First delay half-life is almost equal to doubling period of periodical papers growth and slightly lower average cited half-life of remote sensing journals (7.1, Table 1). So aging of the literature in remote sensing science is very close to that in technical (Burton and Kebler, 1960) or medical (Tsay, 1998) literatures.

It is notable that according to Figure 5 "current" literature in remote sensing is all publications issued in 1955-2005. In other words 99% of published works still used in remote sensing belong to "current" literature domain and only 1% of cited works is older then 50 years. This is obviously because the remote sensing science is still young.

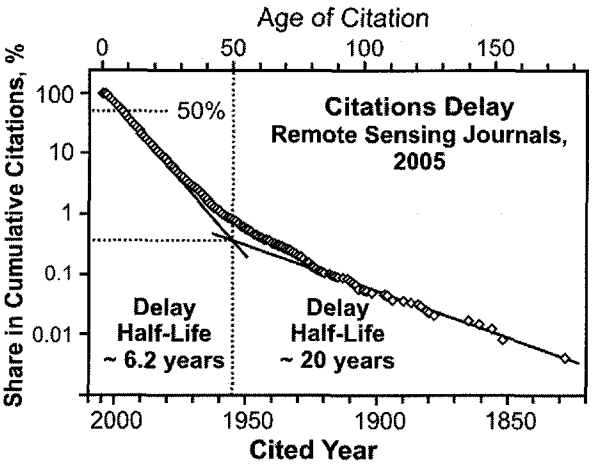

Figure 5. Citation delay of references in remote sensing journals published in 2005. Data from ISI SCI-Expanded database.

3.5 Impact of Remote Sensing Journals

The ISI Journal Citation Report assigns to subject category of remote sensing 10 journals (Table 1). These journals annually publish 20-370 citable items. Half of them are small enough (less then 100 papers per year); three journals are large (more then 200 issued papers annually). In average these journals publish by 35% more papers per year as compared to average of all Earth sciences journals (Table 1). But they receive citations by only 5% more, and their average impact factor is slightly lower then that of all geosciences journals. An average immediacy index of remote sensing journals is less then that of all geojournals by 50%. It means that the "instantaneous" citations (citing papers published in the same year) are infrequent in remote sensing. Probably it is due to wide scattering of remote sensing literature discussed in **Section 3.3**.

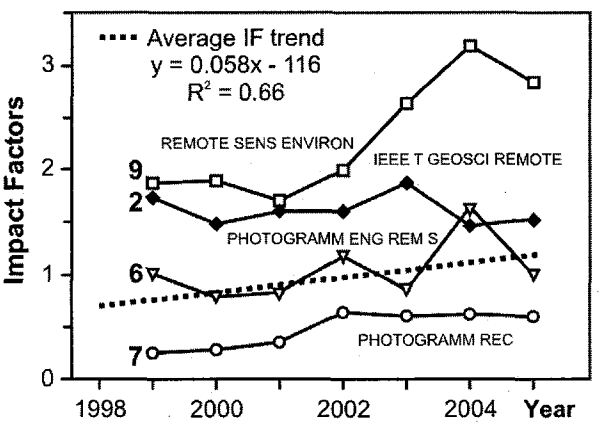

Figure 6. Impact factors of some remote sensing journals, 1999-2005 (numbering see in Table 1). Dotted line is a trend of average impact factors of all ISI-covered remote sensing journals. Data from Thomson-ISI Journal Citation Report and Ren & Rouseau, 2002.

Table 1. Basic publication and citation data of remote sensing journals. Data from Thomsom-ISI Journal Citation Report, 2005. Start years are from Ulrich's Periodicals Directory.

No	Abbreviated Journal Title	ISSN	Start year	Total Cites	Impact Factor	Immediacy Index	Source Items	Half-life, years
1	CAN J REMOTE SENS	0703-8992	1975	537	0.862		41	4.9
2	IEEE T GEOSCI REMOTE	0196-2892	1963	5613	1.627	0.303	290	6.5
3	INT J REMOTE SENS	0143-1161	1980	5309	0.925	0.182	369	7.4
4	ISPRS J PHOTOGRAMM	0924-2716	1949	447	1.674	0.000	22	6.4
5	J GEODESY	0949-7714	1927	605	1.205	0.160	75	4.7
6	PHOTOGRAMM ENG REM S	0099-1112	1934	2402	1.000	0.159	107	9.7
7	PHOTOGRAMM REC	0031-868x	1953	142	0.594	0.235	17	7.2
8	RADIO SCI	0048-6604	1966	2391	0.951	0.191	110	>10.0
9	REMOTE SENS ENVIRON	0034-4257	1968	6543	2.833	0.346	231	6.9
10	SURV REV	0039-6265	1931	68	0.137	0.000	29	
Average of 10 remote sensing journals				2406	1.181	0.175	139	7.1
Average of 689 Earth Sciences journals				2292	1.296	0.269	102	7.2

Basic publication and citation data of geosciences journals evaluated from ISI Journal Citations Report, 1998 (Ren and Rouseau, 2002) show the same features in comparison of remote sensing journals with all geosciences journals. These parameters are all but increased by 50-70% in 2005. In the Figure 6 the trend of average impact factors (1998-2005) of remote sensing journals is shown along with the changes of impact factors of some journals listed in Table 1. This trend (R^2 value is 0.66) demonstrates ~10% per year increase of the impact of those journals. The dramatic change of impact factor of *Remote Sensing of Environment* journal favors the view that in recent years remote sensing applications in environmental studies increase both in number (see Figure 4c) and impact.

4. CONCLUSIONS

The bibliometric analysis of remote sensing literature shows it is still young science with growth rate higher then that of other Earth sciences. Some applications of remote sensing (for example in ecology and environmental studies) shoot up even greater.

Currently we experienced an information boom in remote sensing. The literature on the subject is quite extensive, widely spreaded between source titles and scientific disciplines. That is why the scientists have no time to read and/or to cite latest papers in their publications. All one need to do is to use the abstract services or bibliographic databases to find all publications of interest.

According to results obtained we may predict the number of papers which will be published on remote sensing worldwide in next six years. Is remote sensing community ready to deal more then 3500 papers per year or to keep track of information, published in the books on remote sensing? Whether you like it or not it is real life!

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