



Tropical forests as a target of global scientific production and the comparative position of Brazil*

Selvas tropicales como objetivo de producción científica y la posición comparativa de Brasil

Florestas tropicais como alvo da produção científica global e a posição comparativa do Brasil

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Abstract

This research article was focused on the scientific production of the world on the topic Tropical Forests, based on the articles published by the 20 main countries that compose the Web of Science Data Base, published by Institute for Scientific Information (ISI), which published 90% of the world's total production covering the period 1901 and 2012. The evolution of this production goes from 2 articles in 1901 to 3,554 in the year 2012. The publications in the period are mainly from the USA (14,145 articles) and Brazil (8,324 articles), corresponding the sum of the two countries to 60% of the total publications. The expansion is credited to a set of factors, highlighting the growing importance of tropical forests as an area of geopolitical interest; ecological and conservationists movements; the availability of new imaging technologies and the very gradual growth of world scientific production in recent years. Environmental sciences / ecology is the area of knowledge that registers the largest number of publications (36.8%), but nine other areas, among them, plant sciences (9.8%), agriculture (7.1%), biodiversity conservation (6.6%) and remote sensing (3.4%) also attracted interest for publications about the subject.

Keywords: Scientific production, Forest tropical, Amazon forest, Growth of scientific production, Science and technology

Resumen

Este artículo de investigación está centrado en la producción científica del mundo en el tema Selvas Tropicales, basado en artículos publicados por los 20 principales países que conforman la Red de Base de Datos Ciencia, publicado por el Instituto para la Información Científica (ISI), el cual publica 90% de la producción total mundial cubriendo periodos entre 1901 y 2012. La evolución de esta producción va desde 2 artículos en 1902 a 3.554 en el año 2012. Las publicaciones son principalmente de Estados Unidos (14,145) y Brasil (8,324), corresponde a la suma de las dos naciones el 60% de las publicaciones totales. La expansión se le acredita a una serie de factores, resaltando la creciente importancia de las selvas tropicales como un área de interés geopolítico; ecológico y movimientos conservacionistas; la disponibilidad de tecnologías de escaneo y el crecimiento gradual de la producción científica mundial en los años recientes. Las ciencias ambientales / ecología es el área de conocimiento que registra el mayor número de publicaciones (38.8%), pero otras nueve áreas, entre ellas, ciencia de las plantas (9.8%), agricultura (7.1%), conservación de la biodiversidad (6.6%) y teledetección (3.4%) también atraen interés para publicaciones sobre el tema.

Palabras Clave: Producción científica, Bosque Tropical, Selva amazónica, Crecimiento de la producción científica, Ciencia y tecnología.

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Resumo

Este artigo de pesquisa teve como foco a produção científica mundial sobre o tema Florestas Tropicais, com base nos artigos publicados pelos 20 principais países que compõem o Web of Science data base, publicado pelo Institute for Scientific Information (ISI), que publicou 90% da produção total mundial no período de 1901 a 2012. A evolução dessa produção varia de 2 artigos em 1901 para 3.554 no ano de 2012. As publicações no período são principalmente dos EUA (14.145 artigos) e Brasil (8.324 artigos), correspondendo a soma dos dois países a 60% do total das publicações. A expansão é creditada um conjunto de fatores, destacando a crescente importância das florestas tropicais como área de interesse geopolítico; movimentos ecológicos e conservacionistas; a disponibilidade de novas tecnologias de imagem e o crescimento muito gradual da produção científica mundial nos últimos anos. Ciências ambientais/ecologia é a área do conhecimento que registra o maior número de publicações (36,8%), mas outras nove áreas, entre elas, ciências vegetais (9,8%), agricultura (7,1%), conservação da biodiversidade (6,6%) e sensoriamento remoto (3,4%), também despertou interesse por publicações sobre o assunto.

Palavras-chave: Produção científica, Floresta Tropical, Floresta Amazônica, Crescimento da produção científica, Ciência e tecnologia.

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Introducción

The tropical forests cover approximately 1.433.317.703 hectares Earth's surface and occur in four continents: America, Africa, Asia and Oceania. Reports on the strength and characteristics of these forests are present in the writings of the first Europeans who arrived in the American continent in the XVI and XVII centuries. For example, in the letters of the Jesuit Manoel da Nobrega and other religious and scholars, that were dedicated to the detailed description of the flora and fauna of the tropical forests.

Given their ecological importance, economic potential and contribution to climate regulation and climate changes, the tropical forests are among the ecosystems in which the highest expectations for sustainable development are placed. For these reasons, the concern about the environment includes special attention with the forests. In this sense, the Rio-92 International Conference, also called the Eco-92 or Earth Summit, was an important event that aroused greater interest in the environment in worldwide scale and, with that, the greatest concern with the forest systems. Held 20 years after the first Stockholm-Sweden Conference, Rio-92 marked the recognition of the concept of responsible development and planning of actions with the aim of minimizing the effects of human action on the environment, taking into account the economic, environmental and social factors in order to ensure the sustainability to the development of the nations.

In the particular case of the Amazon Rainforest, which occupies a great territorial extension in Brazil and in eight other countries in South America, and in addition to that, presents immense biodiversity, its strength arouses outstanding interest of many nations and international organizations that seek to obtain more knowledge about this valuable natural heritage still quite poorly known. In the Amazon Region, the housing aspect also occupy a prominent position because of the low-density population in general and a high urban population concentrated in

a few cities. In this aspect, according to the Brazilian Institute of Geography and Statistics (IBGE), the whole Brazilian Amazon region accounts for about 5 million people, and only the state of Amazonas had a population of more than three million inhabitants in 2013, mostly residents of the city of Manaus. In addition, according to the National Institute of Colonization and Agrarian Reform, the same Brazilian Region still concentrates almost 70% of all Agrarian Reform settlements in the country, transforming the region into one of the main destinations of landless workers, thus generating a typical scenario of social interest that requires specific focus for the adoption of public policies.

In Brazil, the concern about the environment, including a special attention to tropical forests, is included in the Federal Constitution of 1988. The First article of Chapter 6 of the Constitution specifies, "Everyone has the right to an ecologically balanced environment, to the good of common use of people and essential to a healthy quality of life, imposing to the public power and to the collective the duty to defend and preserve it for present and future generations".

The effort to preserve and to promote the rational and sustainable use of such a great natural wealth such as the tropical forests necessarily passes through the scientific knowledge. This article presents a study about the world scientific production obtained in the publications that have as a theme the tropical forests. This study was conducted using the Web of Science (Institute for Scientific Information - ISI) Database covering the long period from 1901 to 2012. The data obtained allow us to present: i) the countries with the largest tropical forest areas and their scientific production. ii) a ranking of the countries based on individual scientific production on the subject; iii) identify the areas of knowledge where the publications were made; iv) the most principal authors; v) the most productive institutions; vi) the most significant journals; and vii) the most principal agencies that financed these works.

The issue has had a significant increase of interest since the end of the decade of 1990. This increase can be credited to the growing importance of the tropical forests as an area of geopolitical and economic interest; to the ecological, conservationist's movements and the big attention the subject started to have at the end of the Twentieth Century, after the Conference Rio 92; the advancement of new imaging technologies and growth of the scientific production in recent years in the world. In the case of Brazil, it can be added to these reasons the development of the postgraduate education (Almeida & Guimarães, 2013a), which made the country one of the leaders, along with the USA, in publications about tropical forests.

II. Methodology

The data and indicators for scientific production used in this research article were extracted from the Web of Science, ISI, Clarivate, Philadelphia, USA, covering the period 1901 to 2012; the data were extracted from the online database at the time indicated in the tables.

The search considered proceeding papers, complete articles and review articles with the topic "amazon and/or tropical forest" published in that period. The fields of knowledge represented by the publications were identified, as were the authors and their institutions. The indicators were drawn from the above-mentioned sources of data, considering the standard database nomenclature for the fields of knowledge and using the field classification and original terminology in English.

Intrinsic to the methodology is the identification of event of double counting of scientific articles, which happen when considering the production in diverse fields of knowledge, institutions or countries (Almeida & Guimarães, 2013a). This is due to the fact that whenever any published article is resultant from the scientific collaboration between researchers connected to two or more research institutions or countries, the article will be counted

two or even more times, depending on the case (Zanotto, Haeffner & Guimarães, 2016). Even though, the quantity of the production of each country, or of specific institutions, does not consider double counting. Nor does double counting come about with the number of articles in each journal, since articles are connected to one and only one periodical. However, the total of the data of these variables (country, journal title or institution) is subject to double counting.

According to Zanotto et al. (2016):

Double counting is inherent to bibliometric measures of scientific production of countries, fields of research and institutions. In our study, we identified this as a negotiation related to a large number of articles resulting of international collaboration, especially from the less productive to the more developed countries.

It is important to clarify that not all research is published in English and not all are referenced in WoS. Many of the publications may be in Mandarin, Spanish and Portuguese, and probably many of them are not referenced in WoS.

III – Results and Discussion

I. Distribution of the Areas of Tropical Forests

It was first listed the countries that have areas of Tropical Forests. The Tropical Forests occur in South America (mainly in the Amazon Basin), Central America to the north of the equator, Australia, West and Central Africa, and also, in Asia (Encyclopedia Britannica).

Table 1 shows the distribution and the size of the areas of the Tropical Forests in their respective regions of the world in 2000. The total area of Tropical Forests is 1.433.317.703 hectares (ha). For each continent, the Table also lists the 85 countries, the areas in hectares of the Tropical Forests and the percentage of the area in relation to the total area of Tropical Forest in the world.

Table 1
Countries and their areas of tropical forests

Ordeira - total	Order in the Continent	Continent/Country	AREA OF TROPICAL FOREST (ha) (FAO 2000)	% OF PARTICIPATION IN THE TOTAL AREA OF THE TROPICAL FORESTS IN THE CONTINENTS	Ordeira - total	Order in the Continent	Continent/Country	AREA OF TROPICAL FOREST (ha) (FAO 2000)	% OF PARTICIPATION IN THE TOTAL AREA OF THE TROPICAL FORESTS IN THE CONTINENTS
		South America	757.018.775	52,82	39	29	Kenya	895.535	0,06
1	1	Brazil	508.548.849	35,48	40	30	Burundi	219.171	0,02
2	2	Peru	65.306.922	4,56	41	31	Rwanda	159.946	0,01
3	3	Colombia	51.455.383	3,59	42	32	The Gambia	72.098	0,01
4	4	Venezuela	40.614.896	2,83	43	33	Zimbabwe	64.319	<0,01
5	5	Bolivia	37.307.477	2,6			Asia	233.827.809	16,31
6	6	Guyana	18.325.122	1,28	44	1	Indonesia	98.627.786	6,88
7	7	Suriname	14.650.280	1,02	45	2	China	32.803.000	2,29
8	8	Ecuador	10.017.652	0,7	46	3	Myanmar	24.669.981	1,72
9	9	French Guiana	6.154.164	0,43	47	4	India	22.952.303	1,6
10	10	Paraguay	4.638.030	0,32	48	5	Malaysia	13.692.263	0,96
		Africa	346.874.508	24,20	49	6	Laos	9.705.830	0,68
11	1	Democratic Republic of the Congo	105.806.572	7,38	50	7	Thailand	7.231.566	0,5
12	2	Central African Republic	28.519.059	1,99	51	8	Vietnam	6.206.615	0,43
13	3	Zambia	20.252.674	1,42	52	9	Philippines	5.399.262	0,38
14	4	Republic of Congo	19.451.755	1,36	53	10	Cambodia	4.588.818	0,32
15	5	Cameroon	18.428.207	1,29	54	11	Nepal	3.815.157	0,27
16	6	Gabon	17.343.493	1,21	55	12	Bhutan	2.318.446	0,16
17	7	Tanzania	15.569.010	1,09	56	13	Sri Lanka	806.442	0,06
18	8	Angola	13.591.854	0,95	57	14	Bangladesh	558.947	0,04
19	9	Nigeria	12.325.531	0,86	58	15	Brunei	440.000	0,03
20	10	Sudan	12.137.068	0,85	59	16	Pakistan	7.938	<0,01
21	11	Madagascar	11.793.086	0,82	60	17	Singapore	3.456	<0,01
22	12	Ivory Coast	10.298.174	0,72			Mexico, Central America and Caribbean	61.452.491	4,29
23	13	Ghana	8.053.041	0,56	61	1	Mexico	40.938.401	2,86
24	14	Guinea	5.966.190	0,42	62	2	Nicaragua	4.644.186	0,32
25	15	Ethiopia	5.990.290	0,42	63	3	Guatemala	3.435.373	0,24
26	16	Mozambique	6.107.711	0,43	64	4	Honduras	3.634.100	0,25
27	17	Uganda	5.518.297	0,39	65	5	Panama	2.506.343	0,17
28	18	Liberia	4.313.639	0,3	66	6	Belize	1.928.198	0,13
29	19	Benin	3.688.577	0,26	67	7	Costa Rica	1.038.286	0,13
30	20	Chad	3.613.921	0,25	68	8	Cuba	1.484.723	0,1
31	21	Mali	3.365.207	0,23	69	9	Dominican Republic	915.641	0,06
32	22	Malawi	2.817.705	0,2	70	10	Puerto Rico	281.628	0,02
33	23	Senegal	2.417.870	0,17	71	11	Jamaica	103.048	0,01
34	24	Burkina Faso	1.960.815	0,14	72	12	Trinidad & Tobago	131.243	0,01
35	25	Guinea-Bissau	1.933.816	0,13	73	13	Bahamas	114.055	0,01
36	26	Equatorial Guinea	1.674.603	0,12	74	14	El Salvador	86.745	0,01
37	27	Sierra Leone	1.388.692	0,1	75	15	Guadaloupe	81.593	0,01
38	28	Togo	1.136.581	0,08	76	16	Dominica	38.603	<0,01
39	29	Kenya	895.535	0,06	77	17	Martinique	37.726	<0,01
					78	18	Haiti	13.996	<0,01

Ordeira - total	Order in the Continent	Continent/Country	AREA OF TROPICAL FOREST (ha) (FAO 2000)	% OF PARTICIPATION IN THE TOTAL AREA OF THE TROPICAL FORESTS IN THE CONTINENTS
79	19	Saint Kitts & Nevis	11.406	<0,01
80	20	Saint Vincent and the Grenadines	8.773	<0,01
81	21	Granada	5.264	<0,01
82	22	Antigua and Barbuda	8.773	<0,01
83	23	Saint Lucia	4.387	<0,01
		Oceania	34.144.119	2,38
84	1	Australia	sd	
85	2	Papua New Guinea	34.144.119	
TOTAL - 85 countries			1.433.317.703	100

Source: Moraes (2007). As áreas tropicais úmidas e as febres her geográfica na área ambiental e na de saúde.

South America has the largest area: 52.8% of the total in the world, corresponding to 757,018,775 hectares (ha), or approximately 7.6 million square kilometers. Brazil is the country that has the largest area: 35.5%, representing about 40% of the Brazilian territory. Other countries of the continent also have tropical forests in their territories, but in much smaller extensions. They are Peru (4.5%); Colombia (3.6%); Venezuela (2.8%); Bolivia (2.6%). The other countries in the region are between 1.3% and 0.3% of the world's tropical rainforest area.

Among the other continents, Africa stands second in the world, with 346,874,508 corresponding to 24.2% of tropical forests. In the African continent, seven countries (Democratic Republic of Congo, Central African Republic, Zambia, Republic of Congo, Cameroon, Gabon and Tanzania) together hold about 65% of the total area of these forests in Africa. The others (26 countries) have each one, territories with less than 1% of the total area of the world covered by tropical forests in Africa.

The Asian continent concentrates 16.3% or 233,827,809 ha of tropical forest areas. The countries with the largest extensions are: Indonesia with

6.9%; China with 2.3%; Myanmar 1.7%; India 1.6% and Malaysia 1.0%, making a total of 192,745,333 ha (82.4% of the Continent). The other 12 countries, each one, have less than 0.7% of areas with tropical forests.

Including Mexico in Central America and the Caribbean we observe that the group of these countries hold 4.3% (61,452,491 ha) of tropical forest areas. With 40,938,401 ha (66.6% of this total), Mexico concentrates 2.9% of the world's areas and the remaining 21 countries together account for 1.4% of these areas.

IV – Scientific Production in Tropical Forest

1) Evolution of publications and major countries: Tropical Forests as a research topic have been undervalued for several decades in the last century and in the previous centuries. However, with the promotion of international conferences in climate and ecology, especially the Rio-92, there was a strong awakening to scientific research about such ecosystems. Figure 1 shows the growth of the production of scientific articles in tropical forests in the world in the period of 112 years (1901-2012).

A detailed study about the data collected in the WOS indicates that the first publications on tropical forests in the year 1901 were only two articles. Starting in the 50-decade of the last century, the number of articles varied between one and six. In the interval of time 1951-1960, there were 21 articles published. These numbers increased in the late 1960s. In the period 1961-70, 98 articles were published; between 1971-1980, the number was 356 articles and in the decade of 1981-1990, 1,083 articles in a continuous increase as can be seen in Figure 1. Since the decade of 1981-1990 started a strong increase in the production of articles; since 1998 the number of annual publications has always been in the thousands, reaching 10,083 articles in the triennium 2010-2012, which compared to the decennial 1982-1992, represents an increase of seven 7 times in twenty years. Thus, publications began to increase significantly in the nineties, coinciding with the Rio-92 conference.

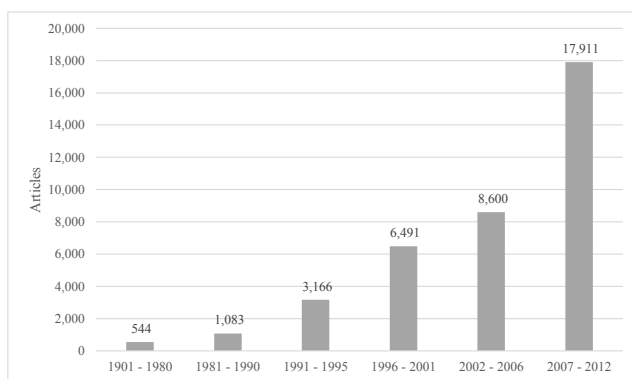


Figure 1. Production of Articles in Tropical Forests in the World.

Source: WoS.

Apparently, the observed increase can be credited to some peculiarities: the natural increase of the scientific production as a result of the development of the scientific work in worldwide level; increased interest in tropical forests along with the ecological and conservationist movement, especially in societies of developed countries; the advancement of new technologies, such as satellite imagery; computer resources that have become important working tools for researchers; acknowledgment of tropical forest areas as areas of development and economic investment, whether for preservation or for the implantation of new areas of agribusiness or human settlements; worldwide interest in environment resulted by the success and the impact caused by the Rio-92 Conference. In the case of Brazil, the outstanding expansion of postgraduate programs with the training of thousands of new human resources at the masters and the doctoral levels (Almeida & Guimarães, 2013b).

It can be observed that the recent growth of the scientific production at the world level can be credited to the contribution of several countries. Table 2 lists the 20 most prominent countries. Several countries that do not have tropical forests have made significant contributions to the new scientific knowledge about these ecosystems.

It can be seen that the USA and Brazil together account for about 60% of this production. Other countries such as England and Germany (7.5% each); France (6.0%) and Australia (5.6%) have a

Table 2:

World Scientific Production on Tropical Forests: Top 20 Countries

Ranking	Country	Articles 1901-2012	% World	1982-1992 (A)	2002-2012 (B)	Recent Growth *Times (B/A)
1	USA	14.145	37,4	1.131	9.546	8
2	BRAZIL	8.324	22,2	351	6.595	19
3	ENGLAND	2.832	7,5	148	2.251	15
4	GERMANY	2.826	7,4	107	2.067	22
5	FRANCE	2.286	6,0	100	1.628	16
6	AUSTRALIA	2.117	5,6	80	1.513	19
7	MEXICO	1.726	4,5	77	1.327	19
8	CANADA	1.610	4,3	59	1.214	21
9	JAPAN	1.276	3,4	52	1.129	22
10	CHINA	1.240	3,3	51	978	19
11	NETHERLANDS	1.187	3,1	49	887	18
12	INDIA	1.122	3,0	38	827	17
13	SPAIN	822	2,2	38	736	19
14	PANAMA	818	2,1	37	624	19
15	SCOTLAND	705	1,9	36	524	15
16	COLOMBIA	646	1,7	30	508	17
17	SWITZERLAND	614	1,6	22	503	23
18	VENEZUELA	584	1,5	22	459	19
19	PERU	571	1,5	22	438	20
20	MALASIA	555	1,4	21	433	21
TOTAL OF THE TABLE		34.134*	90,02	1.726*	24.107*	14
WORLD		37.915	100,0	2.078	26.511	13

Recent growth: Comparison of the production in the decades 2002-2012 versus 1982-1992. * Not counted the double counting of articles with authors from more than one country. The sum of articles is subject to double counting.

significant contribution. Apparently, there are at least three reasons for the greater contribution of the USA and Brazil: i) the high scientific development and leadership of the USA in the worldwide ranking of scientific publications; ii) the existence of the largest tropical forest in the Brazilian territory, together with the great growth of the national scientific production that in 2009 led the country to the 13th place in the ranking of the countries with the highest number of published scientific articles (Almeida & Guimarães, 2013b); iii) the development of postgraduate courses in Brazil, namely: expansion of 183 courses and 880 students enrolled in 1973 to 1,606 courses with 71,387 students enrolled in 2011 (Almeida & Guimarães, 2013a).

Analyzing Table 2 the growth of recent scientific production (comparison of the intervals between the years 1982-1992 and 2002-2012) in the performance per country, it is noted an extraordinary advance between these two decades for all the countries (average of 14 times) and in the world (13 times).

As noted above, there is a marked interest of the countries that do not have tropical forests in their territories to study these ecosystems, as it can be observed with the USA, England, France, Canada,

Germany and others. It is worth noting that England, France, Holland and Spain, although they do not have tropical forests in their territories, they had historical political connections with the countries located in the tropics.

2) Scientific areas of publications in Tropical Forests: Corroborating the affirmation that the increase of the interest of the researchers in tropical forests could be linked to the ecological and conservationist movement, it can be seen in Figure 2 that 36.83% of the publications were in the Environmental Sciences & Ecology, a much higher proportion than the 9.84% of Plant Sciences. The other areas maintain very different percentages: Forestry, 9.33%; Geology, 7.74%; Agriculture, 7.09%; Biodiversity, 6.58%; Zoology, 6.51%; Meteorology, 5.60%; Geography, 3.43% and Remote Sensing, 3.42%. It is worth noting that this last area is relatively new and strictly related to the development of new technologies, mainly through the images obtained by satellite. We also investigated the SCIVAL Base (Scopus Platform, Elsevier) for this distribution of scientific production on Tropical Forests by areas of knowledge. In spite of the differences in the shorter period covered by the Scival Base (2010 - 2014) and some differences in the classification of areas, it was verified (data not shown), that such distribution is similar in both bases, being that: i) The environmental sciences represent a large percentage of publications in both databases; ii) Agriculture is also an expressive part of the articles in both WoS and SCIVAL; iii) Despite its importance in the study of tropical forests, the SCIVAL database does not present separate data for the remote sensing area, which is considered a technology that has strongly contributed to the recent progress of researching in tropical forest.

3) Importance of the remote sensing: In general, the scientific advancement has benefited from the development of space technologies. Multidisciplinary, remote sensing integrates knowledge of mathematics, computing, physics, chemistry, statistics, geography and other areas.

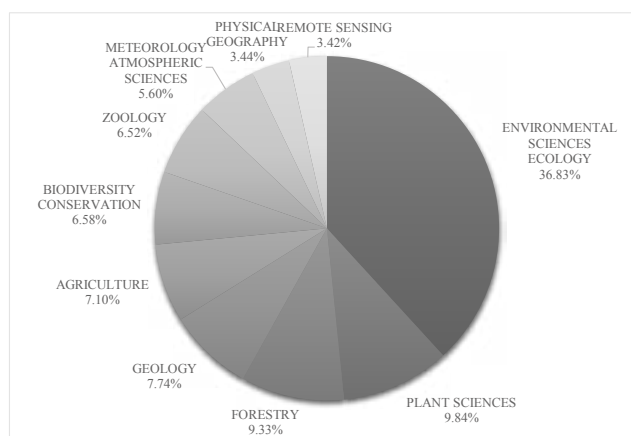


Figure 2: Areas of knowledge of the published articles
 Source: WoS.

Starting from the analysis of the aerial photographs, this field had a great qualitative increase with the orbital images obtained by the artificial satellites since 1960. Brazil is present in this field since the beginning, developing research in the field of space science and technology. Coordinated by the Brazilian Space Agency, the work ranges from the construction of satellites that collect data to remote sensing of the Earth, which are used in meteorology and in various monitoring: water resources, environmental, atmosphere, territorial management.

The images obtained through the remote sensing allow the researchers to identify the location of the geographic aspects, biomes and their characteristics, and through the interpretation of the images, mapping and monitoring of extensive areas in different dates.

In the studies about Forests, the importance of Remote Sensing can be verified in the percentage of publications (3.42%) shown in Figure 2, despite its relatively recent appearance.

4) Most prominent institutions in scientific production of Tropical Forests: Various institutions disseminate the publication of articles on tropical forests. Table 3 lists the 25 institutions (9 American and 9 Brazilian) that published the most

in the period studied, in a total of 16,786 (44.3%) of the articles published. It is worth to mention that two institutions lead the ranking: The University of California with 1,657 (4.37%) and the University of São Paulo with 1,650 (4.35%) publications. Institutions from seven other countries have also published a highlighted number of articles about the subject: National Autonomous University of Mexico (Mexico), 913; Chinese Academy of Science (China), 680; Max Plant Society (Germany), 528; Institut National de la Recherche – INRA (France), 468; Wageningen University Research Center (Holland), 422; University of Gottingen (Sweden), 407; Commonwealth scientific Industrial Research Organisation – CSIRO (Australia), 401.

On the American side, eight other institutions stand out: Florida State University, 2.74%; Smithsonian Tropical Research Institute, 2.47%; United States Department of Agriculture, 2.11%; University of Florida, 1.91%;

Among the group of institutions that hold between 3% and 1% of the publications are the Instituto Nacional de Pesquisas Espaciais, Empresa Brasileira de Pesquisa Agropecuária, Universidade Federal do Rio de Janeiro, Universidade de Brasília, Fundação Oswaldo Cruz, Universidade Estadual Paulista e a Universidade Estadual de Campinas.

We can also verify that the USA and Brazil, each has 9 institutions among the 25 that publish the most.

Institutions	Country	Number	% world
1 UNIVERSITY OF CALIFORNIA SYSTEM	United States	1657	4,374
2 UNIVERSIDADE DE SAO PAULO	Brazil	1650	4,355
3 FLORIDA STATE UNIVERSITY SYSTEM	United States	1036	2,735
4 SMITHSONIAN TROP RES INST	United States	936	2,471
5 NATIONAL AUTONOMOUS UNIVERSITY OF MEXICO	Mexico	913	2,41
6 UNITED STATES DEPARTMENT OF AGRICULTURE USDA	United States	799	2,109
7 INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS INPE	Brazil	746	1,969
8 UNIVERSITY OF FLORIDA	United States	724	1,911
9 CHINESE ACADEMY OF SCIENCES	China	680	1,795
10 UNITED STATES FOREST SERVICE	United States	613	1,618
11 EMPRESA BRASILEIRA DE PESQUISA AGROPECUARIA EMBRAPA	Brazil	602	1,589
12 FED UNIV PARA	Brazil	570	1,505
13 MAX PLANCK SOCIETY	Germany	528	1,394
14 NATIONAL AERONAUTICS SPACE ADMINISTRATION NASA	United States	521	1,375

Institutions	Country	Number	% world
15 UNIVERSIDADE FEDERAL DO RIO DE JANEIRO	Brazil	497	1,312
16 HARVARD UNIVERSITY	United States	488	1,288
17 UNIVERSITY OF CALIFORNIA BERKELEY	United States	471	1,243
18 INSTITUT NATIONAL DE LA RECHERCHE AGRONOMIQUE INRA	France	468	1,235
19 UNIVERSIDADE DE BRASILIA	Brazil	442	1,167
20 WAGENINGEN UNIVERSITY RESEARCH CENTER	Netherlands	422	1,114
21 FUNDAÇÃO OSWALDO CRUZ	Brazil	414	1,093
22 UNIVERSIDADE ESTADUAL PAULISTA	Brazil	410	1,082
23 UNIVERSITY OF GOTTINGEN	Sweden	407	1,074
24 COMMONWEALTH SCIENTIFIC INDUSTRIAL RESEARCH ORGANISATION CSIRO	Australia	401	1,058
25 UNIVERSIDADE ESTADUAL DE CAMPINAS	Brazil	391	1,032

Sources: WoS

VIII – Top Authors

The fifty authors with the most published articles can be seen in Figure 3. The author with the most published articles, Artaxo P., has an address the Brazilian institution (USP), other seven authors (Peres, CA; Martinelli LA; Fearnside PM; Cerri CC; Shimabukuro YE, Victoria RL, Camargo, LMA) also conduct work at Brazilian institutions. As expected, given the leadership in the publication of articles, 44% of the authors have as addresses North American institutions.

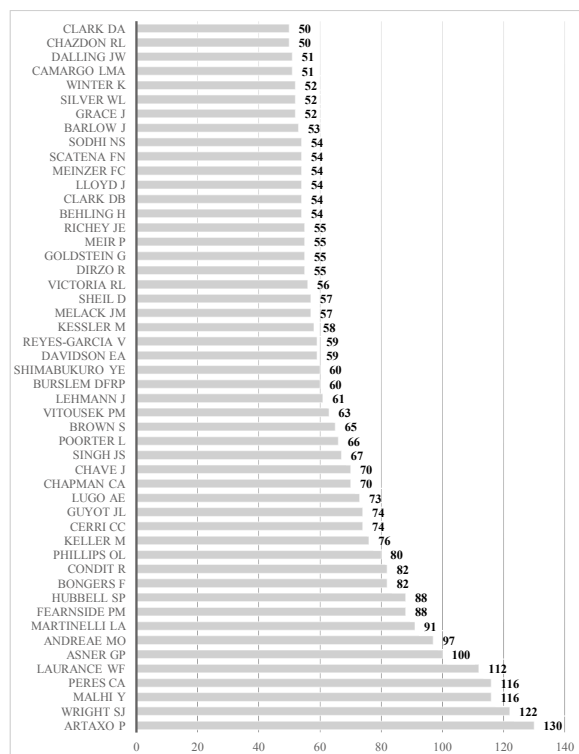


Figure 3: Authors who published the most

Source: WoS

IX – Periodicals that most published articles on Tropical Forests in the period 1901-2012

Table 4 lists the journals that have published at least 100 articles on Tropical Forests in the period 1901 - 2012. In the Table, are listed 66 journals that together published 39% of the articles in the Tropical Forests area. Of that total, 20 titles are published in the USA, followed by England with 17 titles and Netherlands with 15 titles. Germany publishes 4 titles and the remaining 10 countries only one title each.

Table 4. Periodicals with larger numbers of articles published respective countries and factor of impact.

PERIODICALS	COUNTRY	ARTICLES	IMPACT FACTOR
FOREST ECOLOGY AND MANAGEMENT	NETHERLANDS	1055	2,667
BIOTROPICA	USA	1044	2,082
JOURNAL OF TROPICAL ECOLOGY	USA	788	1,222
BIODIVERSITY AND CONSERVATION	NETHERLANDS	498	2,065
JOURNAL OF GEOPHYSICAL RESEARCH ATMOSPHERES	USA	466	3,440
ECOLOGY	USA	461	5,000
OECOLOGIA	GERMANY	454	3,248
BIOLOGICAL CONSERVATION	ENGLAND	386	4,036
JOURNAL OF ECOLOGY	ENGLAND	314	5,694
CONSERVATION BIOLOGY	USA	300	4,320
JOURNAL OF BIOGEOGRAPHY	ENGLAND	296	4,969
PLANT ECOLOGY	NETHERLANDS	284	1,640
INTERNATIONAL JOURNAL OF REMOTE SENSING	ENGLAND	281	1,359
GLOBAL CHANGE BIOLOGY	ENGLAND	273	8,224
REMOTE SENSING OF ENVIRONMENT	USA	254	4,769
PLOS ONE	USA	251	3,534
REVISTA DE BIOLOGIA TROPICAL	COSTA RICA	244	0,610
ECOLOGICAL APPLICATIONS	USA	239	4,126
IEEE INTERNATIONAL SYMPOSIUM ON GEOSCIENCE AND REMOTE SENSING IGARSS	USA	238	1,809
PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA	USA	221	9,809
AMERICAN JOURNAL OF BOTANY	USA	219	2,463
ZOOTAXA	NEW ZEALAND	218	1,060
PLANT AND SOIL	NETHERLANDS	180	3,235
ATMOSPHERIC CHEMISTRY AND PHYSICS	GERMANY	174	5,298
AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE	USA	173	2,736
GEOPHYSICAL RESEARCH LETTERS	USA	172	4,456
MEMORIAS DO INSTITUTO OSWALDO CRUZ	BRAZIL	170	1,566
BIOGEOCHEMISTRY	NETHERLANDS	169	3,730
OIKOS	DENMARK	169	3,559
JOURNAL OF VEGETATION SCIENCE	ENGLAND	167	3,372
INTERCIENCIA	VENEZUELA	166	0,248
JOURNAL OF HYDROLOGY	NETHERLANDS	158	2,693
PALAEOGEOGRAPHY	NETHERLANDS	152	2,752
PALAEOCLIMATOLOGY	NETHERLANDS	149	4,410
PALAEOECOLOGY	NETHERLANDS	148	31,447
SOIL BIOLOGY BIOCHEMISTRY	ENGLAND	146	2,696
SCIENCE	USA	146	4,904
HYDROLOGICAL PROCESSES	ENGLAND	146	2,696
JOURNAL OF CLIMATE	USA	146	4,904
AGRICULTURE ECOSYSTEMS ENVIRONMENT	NETHERLANDS	141	3,203
GLOBAL BIOGEOCHEMICAL CYCLES	USA	140	4,528
TREE PHYSIOLOGY	CANADA	140	3,405
NEW PHYTOLOGIST	ENGLAND	139	6,373

PERIODICALS	COUNTRY	ARTICLES	IMPACT FACTOR
AUSTRAL ECOLOGY	AUSTRALIA	135	1,724
MOLECULAR ECOLOGY	ENGLAND	135	5,840
ECOLOGICAL RESEARCH	JAPAN	130	1,513
AGROFORESTRY SYSTEMS	NETHERLANDS	127	1,240
ECOLOGICAL MODELLING	NETHERLANDS	127	2,326
AMBIO	NORWAY	125	2,973
FUNCTIONAL ECOLOGY	ENGLAND	123	4,857
TREES STRUCTURE AND FUNCTION	USA	123	1,869
AMAZONIANA LIMNOLOGIA ET OECOLOGIA REGIONALIS SYSTEMAE FLUMINIS AMAZONAS	GERMANY	119	0,213*
AGRICULTURAL AND FOREST METEOROLOGY	NETHERLANDS	114	3,894
ENVIRONMENTAL CONSERVATION	ENGLAND	114	2,320
GLOBAL ECOLOGY AND BIOGEOGRAPHY	ENGLAND	114	7,242
JOURNAL OF APPLIED ECOLOGY	ENGLAND	114	4,754
CLIMATIC CHANGE	NETHERLANDS	113	4,622
AFRICAN JOURNAL OF ECOLOGY	ENGLAND	111	1,000
ECOLOGY LETTERS	ENGLAND	111	13,042
BIOGEOSCIENCES	GERMANY	110	3,753
GEOCHIMICA ET COSMOCHIMICA ACTA	USA	108	4,250
GEODERMA	NETHERLANDS	108	2,509
CURRENT SCIENCE	INDIA	107	0,833
HYDROBIOLOGIA	NETHERLANDS	105	2,212
HUMAN ECOLOGY	USA	103	1,076
ECOSYSTEMS	USA	102	3,531
ECOLOGICAL ECONOMICS	NETHERLANDS	101	2,517
ATMOSPHERIC ENVIRONMENT	ENGLAND	100	3,062

Source: WoS

The data in Table 4 show that publications are sprayed. Three journals each contain less than 3% of the articles: Forest Ecology and Management (1,055 articles, 2.79%), Biotropic (1,044 articles, 2.76%) and Journal of Tropical Ecology (788 articles, 2;08%). With less than 2% of the publications are five journals: Biodiversity and Conservation (498 articles, 1.31%), Journal of Geophysical Research Atmospheres (466 articles, 1.23%), Ecology (461 articles, 1.22% Oecology (454 articles, 1.20%), Biological Conservation (386 articles, 1.02%). Most journals have published less than 1% of the articles in an eloquent picture of spraying on one hand, and on the other hand the interest and importance of the subject. Brazil has only one journal in this ranking, Memórias do Instituto Oswald Cruz with 170 (0.44%) published articles.

The important indicator of the impact factor of the periodicals was also raised. The qualitative indicator points to the "frequency with which a work is quoted" (Almeida & Guimarães, 2010) and was used here as an impact index of the periodicals indicating the proportion of the most cited articles in each case. The journal Science (England) with

an index of 31,447 was the journal with the highest impact factor in Table 4 followed by Ecology Letters, also published by England with impact factor 13,042 and Proceedings of the National Academy of Sciences of the United States of America with a rate of 9,809.

X. Financing Agencies

Survey carried out in WoS shows that 30 funding agencies of scientific research were responsible for funding 85% of the work on tropical forests in the period from 1946 to 2012.

Table 5
Financing Agencies

AGENCY	%	COUNTRY
1 CONSELHO NACIONAL DE DESENVOLVIMENTO CIENTÍFICO E TECNOLÓGICO (CNPQ)	20,43	BRAZIL
2 NATIONAL SCIENCE FOUNDATION	16,71	USA
3 COORDENACAO DE APERFEICOAMENTO DE PESSOAL DE ENSINO SUPERIOR (CAPES)	6,70	BRAZIL
4 FUNDACAO DE AMPARO A PESQUISA DO ESTADO DE SAO PAULO	6,49	BRAZIL
5 NATIONAL NATURAL SCIENCE FOUNDATION OF CHINA	4,86	CHINA
6 NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	3,29	USA
9 NATIONAL SCIENCES AND ENGINEERING RESEARCH COUNCIL OF CANADA	2,03	CANADA
10 EUROPEAN UNION	1,86	EUROPEAN UNION
11 SMITHSONIAN TROPICAL RESEARCH INSTITUTE	1,74	USA
12 NATURAL ENVIRONMENT RESEARCH COUNCIL	1,74	ENGLAND
13 ANDREW MELLON FOUNDATION	1,72	USA
14 DEUTSCHE FORSCHUNGSGEMEINSCHAFT	1,64	GERMANY
15 EUROPEAN COMMISSION	1,57	EUROPEAN UNION
16 AUSTRALIAN RESEARCH COUNCIL	1,55	AUSTRALIA
17 GERMAN RESEARCH FOUNDATION	1,47	GERMANY
18 NATIONAL GEOGRAPHIC	1,43	USA
19 CHINESE ACADEMY OF SCIENCES	1,31	CHINA
20 FUNDACAO DE AMPARO A PESQUISA DO ESTADO DE MINAS GERAIS	1,31	BRAZIL
21 JAPAN SOCIETY FOR THE PROMOTION OF SCIENCE	0,98	JAPAN
22 FUNDACAO DE AMPARO A PESQUISA DO ESTADO DO AMAZONAS	0,93	BRAZIL
23 NATIONAL INSTITUTES OF HEALTH	0,91	USA
24 WILDLIFE CONSERVATION SOCIETY	0,85	USA
25 GERMAN ACADEMIC EXCHANGE SERVICE	0,83	GERMANY
27 SWISS NATIONAL SCIENCE FOUNDATION	0,76	SWISS
28 MINISTRY OF EDUCATION CULTURE SPORTS SCIENCE AND TECHNOLOGY OF JAPAN	0,75	JAPAN
29 FUNDACAO DE AMPARO A PESQUISA DO ESTADO DO RIO DE JANEIRO	0,74	BRAZIL
30 NATIONAL BASIC RESEARCH PROGRAM OF CHINA	0,71	CHINA

Source: WoS

It is observed that the Brazilian institutions occupy strategic positions in financing these research, with emphasis to CNPq and CAPES, Brazilian federal agencies, which together are responsible for financing more than 27% of the articles. Overall, the State Research Support Foundations (FAPEs) present in several Brazilian

states, add up to 9,47% of the funding for the publications. The US National Science Foundation (NSF) also occupies a prominent position in the Table since it is responsible for 16,71% of the funding for studies about the theme Tropical Forests.

XI. Scientific Production of the countries with the largest areas of Tropical Forests

Table 6 highlights the scientific production of the 18 countries that have areas of tropical forests larger than one million hectares and the scientific production of at least 100 scientific articles on the subject during the period 1901 to 2012. The Table details the number of articles published on tropical forests since 1901, the percentage of these articles in relation to the world and the article / area of forests, indicated by number of articles / million hectares (ha).

Table 6.
Scientific Production of selected countries*: Area of tropical forests, articles per million inhabitants and percentage of international collaboration on the theme.

No	Continent/Country	AREA OF TROPICAL FOREST IN HECTARES	NUMBER OF ARTICLES PUBLISHED 1901-2012	% OF ARTICLES IN RELATION TO THE WORLD 1901-2012	ARTICLES PER MILLION OF HECTAR	% OF INTERNATIONAL COLLABORATION 1980-2012
	South America	757.018.775	11.074	29,07	14,6	-
1	Brazil	508.548.849	8.324	22,03	16,4	40,82
2	Peru	65.306.922	571	1,51	8,7	64,81
3	Colombia	51.455.383	646	1,71	12,5	75,61
4	Venezuela	40.614.896	584	1,54	14,4	48,96
5	Bolivia	37.307.477	384	1,01	10,3	90,45
6	Ecuador	10.017.652	305	0,87	30,4	90,70
7	French Guiana	6.154.164	181	0,47	29,4	83,98
	Africa	346.874.508	1.375	1,33	3,9	-
8	Cameroon	18.428.207	180	0,47	9,8	86,11
9	Nigeria	12.325.531	200	0,52	16,2	40,76
10	Uganda	5.518.297	129	0,34	23,4	63,78
	Asia	233.827.809	4.479	9,97	19,2	-
11	Indonesia	96.627.786	532	1,40	5,5	85,19
12	China	32.803.000	1.240	3,28	37,8	49,34
13	India	22.952.303	1.122	2,97	48,9	26,23
14	Malaysia	13.692.263	555	1,46	40,5	77,42
15	Thailand	7.231.566	324	0,86	44,8	76,76
	Mexico, Central America and Caribbean	61.452.491	3.274	8,03	53,3	-
16	Mexico	40.938.401	1.726	4,56	42,2	45,54
17	Panama	2.506.343	818	2,16	325,9	85,02
18	Costa Rica	1.038.256	497	1,31	477,8	75,61

* The countries were selected according to two criteria: area of tropical forest larger than one million hectares (ha) and a scientific production of at least 100 articles in the period 1901 - 2012.

The combined production of these 18 countries corresponds to 18.318 articles accounting for 82% of

the total of 22.319 articles or 67,9% of total area of tropical forests of these 85 countries.

We can note that half of the countries in Table 6 (Brazil, Mexico, China, India, Panama, Colombia, Venezuela, Peru and Malaysia) are also present in Table 2, which lists the 20 largest producers of articles in this topic. Brazil stands out in the quantitative number of publications (8,324 articles), corresponding to 22% of the total in world. A number of countries in Table 6 (Ecuador, Bolivia, Cameroon, Panama, Indonesia, French Guiana, Malaysia, Thailand, Costa Rica and Colombia) study Tropical Forests with a high proportion (more than 70%) of articles produced with the participation of international cooperation (two or more authors from other countries in the publications). Coherently with other observations about the Brazilian science (Zannoto et al, 2016), the international cooperation in articles published by Brazilian authors is also low (40.8%). Also noteworthy in the table is the scientific production per million hectares of Tropical Forests. The data show that the Central American countries (in whose group we included Mexico), especially Costa Rica and Panama (448 and 326 articles per million hectares, respectively) have devoted more studies to their tropical forests. Certainly, in these cases, the strong presence of international cooperation, as demonstrated above for these countries, plays an important role. On the other hand, the countries of Asia and South America, where the greatest extent of these forests are located, have devoted less attention to the study of these ecosystems. In this context, Brazil has a special attention, with only 16,4 articles published per million hectares of its significant Amazon Forest. This circumstance imposes, consequently, deep restrictions to the attempts of sustainable development of the Amazon Forest, the greater natural patrimony of the countries that compose that region in the planet.

In addition, Argentina, that does not have a tropical forest but is located in the region and bordering Brazil, produced 470 scientific articles during 1901-2012.

XII – Final considerations

Attracting attention since the Sixteenth century, Tropical Forests became objects of scientific publications in an expressive way since the end of 1990. The interest increased linked to greater ecological awareness and its movements, notably in the developed world. In addition to the ecological movements, there is also the natural growth of the world scientific production and, in the case of Brazil, the evolution and role of postgraduate studies, where the number of courses increased from 183 in 1976 to 1,606 in 2011 and the number of students enrolled went from 880 to 71,387 in the same period.

In the areas of knowledge related to the subject the presence of ecology is widely highlighted: 36.86% of the published articles. In view of the importance of technologies associated with remote sensing, which provide tools to researchers for monitoring large areas at the time and space, we note the emergence and growth of tropical forest publications in the area of remote sensing that already respond for 3.42% of published articles.

The leadership in the publications is from the USA with 37.44% of the articles, followed by Brazil (22.24%). However, publications are widespread in many countries, including those far from tropical forest areas such as Finland, which published 433 articles in the period 2002-2012. Therefore, an increasing interest in the subject can be seen.

In the SCIVAL database, the articles were published in heavily sprayed areas. Most (27%) is in Agricultural and Biological Sciences journals, followed by Environmental Science (14%), Computer Science (11%), Earth and Planetary Sciences (8%), Medicine (7%), Social Science (%); Biochemistry (5%); Engineering (4%); Immunology and Microbiology (3%); Mathematics (2%); Arts and Humanities (2%) others (11%).

There is no correlation between the number of articles on Tropical Forests and the extent of

territory covered by them. The exception is Brazil that has the largest area of tropical forest (35% of forests) and is the first in number of articles published on the subject among the countries that have this biome. In the world scenario, Brazil is in the second position in the ranking led by the USA. The ten nations that publish the most are USA; Brazil; England; Germany; France; Australia; Mexico, Canada; Japan and China. Of these, the ones that have territories with tropical forests are only Brazil, Australia, Mexico and China.

Regarding the individual participations, Paulo Artaxo, from the University of São Paulo, is the author with the largest number of publications and in his company, in the list of the 50 most published authors in the period, are the seven other authors that have Brazilian institutions as their addresses. As far as research institutions are concerned, the most present is the University of California with 4.37% of publications followed by the University of São Paulo with 4.35%. As with the areas of knowledge, one can see a sprinkling in the 50 institutions that published the most: except for the two leading institutions, almost 50% (24 institutions) concentrate between 1 and 2% of the publications.

Brazilian institutions occupy strategic positions as far as research funding is concerned. CNPq and CAPES, the federal agencies that together are responsible for financing more than 27% of projects, stand out in this function. Also Brazilian, are the Foundations of Support to Research of the States that add up 9.47%. The US National Science Foundation also occupies a relevant position, as it is responsible for 16.71% of the support to researching.

The analysis of the evolution of the production of knowledge about Tropical Forests, allows us to consider that the tendency is of continuous growth of the articles related to this research theme. In addition, in this tendency, Brazil, which still has very little scientific knowledge about the potential of this important ecosystem, despite having the greater part of the Amazon Rainforest and, therefore, the

world's largest reserve of Tropical Forests, will need to assume an increasing role in the research of this topic. The task can be facilitated since the number of researchers increases in the country due to the training of human resources in the robust Brazilian Post-Graduation Program (Almeida a& Guimarães, 2013b). Concentrating the largest tropical forest in the planet, the Amazon attracts the attention of scientists, institutions, companies and world leaders for its geopolitical importance. The initiatives to take a leading role in Amazonian research will require Brazilian governments to adopt public policies that include, in addition to funding, the promotion of basic and applied research and technological innovation.

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