# Growth of Global Warming Publications: A Scientometric Approach

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**ABSTRACT:** *The present study is aimed at analyzing the global publication trends on global warming using Web of Science database for the period 2006-2015. A total of 23335 publications were published during the study period on global warming and the average number of publications per year was 2333.5. The quantum of publications peaked in the year 2015 with a total publications of 3357. This paper analysed the broad features of literature on global warming focusing on year wise growth of publications, most prolific authors, highly productive institutes, highly productive countries, language wise distributions of publications, high productive subject areas and most preferred journals for publications by scientists etc..*

## 1. Introduction

Global warming is a major atmospheric problems faced by all over the world now. Global warming is an increase in the average temperature of the Earth's atmosphere, especially a sustained increase great enough to cause changes in the world climate. In our earth's surface becoming hot day by day by trapping the sun's heat and rise in the level of atmospheric carbon dioxide, results into air polluted fogs in major city which leads into many diseases especially the airborne diseases, the instance for this is the Delhi city. As such, It has become one of the subjects of big social issues which need individual social awareness to a

great level. There are many causes of the global warming some are natural causes and human made causes. The most important cause of global warming is greenhouse gases which are generated by some natural processes as well as human activities. Global warming causes lot of climate changes in the atmosphere such as changes in weather patterns, changes in air circulation patterns, jet stream, rain without season, melting ice caps, declining ozone layer, occurrence of heavy storms, cyclones, flood, epidemic diseases, lack of food and so many effects. Its threatening effects are increasing day by day and creating danger for human life. So the global warming change was a large impact on world agricultural productivity in the coming years. As a result the mankind made rigorous research on the impact of the global warming as well as to find out the ways and means to control it.

This is clear from the research output on the area since 2006 to 2015 recorded in the Web of Science database were increased from a total of 1119 to 3357 publications. Therefore the present study has been undertaken to know the growth of literature in the field of global warming so as to focus the growth pattern of the global warming literature among the researchers in the area.

**Review of Literature**

Xiao Luo (2017) Coalbed methane (CBM) is well recognized as being able to provide clean fuels and reduce carbon dioxide emissions, thereby helping to reduce global warming. The authors by using CiteSpace analyzed large volume of scientific publications on CBM. Shabahat Husain and Muzamil Mushtaq (2015) applied scientometric tools to analyse the literature output on climate change which are indexed in the web of science database. The study mainly focusing on the patterns of citations in the literature. Oh Mihn-Soo et.al (2016) applied scientometric tools to analyse the literature on global warming indexed in web of science. The study found out that the research out on global warming mostly contributed by the countries like USA,UK, China, Japan and Netherlands. Santhakumar and Kaliyaperumal (2015) studied the growth and development pattern of mobile technology literature recorded in the Web of Science database during the period of 2000–2013. The average number of publications published per year was 759.86 and the highest number of publications 1495 were published in 2013. Output of total publications, 9037 were produced by multiple authors and 1601 by single authors. Authors from USA have contributed maximum number of publications. Hanuschild (2016) studied the literature on climate change. This study focuses on the trend of the growth of the literature.

The review reveals that the studies on scientometric applications on the literature of the global warming are minimum in number and that is the research gap inspired to take up this research.

**2. Objectives of the Study**

Though the main objective of this study is to analyse the global research performance in the field of global warming as recorded in the web of science during 2006-2015 in particular, the study focuses on the following aspects:

• To analyse the growth patterns of the global warming research output especially with the use of least square method and prediction of further growth if the trend continuous along with the finding of Annual Growth Rate(AGR) and Combined Annual Growth Rate(CAGR).

• To identify the most prolific authors in terms of quantum of publications' they contributed over the period of study.

• To identify most productive countries in terms of their quantum of literature on the discipline understudy.

• To identify the top 10 ranks of the institutions in terms of the quantum of literature contributed by them.

• To study the most preferred source titles for publication in the field and to identify the high productive subject areas.

**3. Materials and Methods**

The Web of Science database was used for retrieving data on global warming, a total of 23335 publications were downloaded and analysed by using the Microsoft excel for the analysis of the data. The Web of Science database allows us to refine the results in terms of publication years, countries, institutes, authors, language, subjects and source titles. The journal articles and review articles were considered for the analysis.

**4. Data Analysis and Interpretations**

**4.1 Trend Analysis - Method of Least Squares**

The least square method is used to find out the trend in the literature growth and to focus or predict the trend for further ten years from 2016 to 2025. It is a new approach to the field of Scientometric made by this paper. However, this projection for the future may be depends upon the obselence characters of the subject. If the obselence is quick, this may not be suitable. This method works on the following formula:

The straight line trend has an equation of the type: $Y = a + bX$,

Where,

$Y$ represents the estimated values of the trend, $X$ represents the deviations in time period; '$a$' and '$b$' are constants.

The values of two constants '$a$' and '$b$' are estimated by solving the following two normal equations.

$\Sigma Y = Na + b \Sigma X$

$\Sigma XY = a \Sigma X + b \Sigma X^2$

Where $N$ represents number of years for which data is given.

The variable $X$ can be measured from any point of time as origin. To make calculation simpler, it is better to take the mid-point of time as the origin because the negative values of first half of the time series will equalize the positive values in the second half of the series which symbolically gives $\Sigma X = 0$.

When $\Sigma X = 0$, the two normal equations for finding the constants '$a$' and '$b$' will be

$$\Sigma Y = Na \Rightarrow a = \frac{\Sigma Y}{N} = Y$$

$$\Sigma XY = b\Sigma X^2 \Rightarrow b = \frac{\Sigma XY}{\Sigma X^2}$$

This provides that the constant '$a$' is simply equal to the mean of $Y$ values and the constant '$b$' gives the rate of change. The constant '$a$' refers to the $Y$ intercept, i.e. the difference between the point of origin and the point where the trend line touches the $Y$ axis. The constant '$b$' refers to the slope of the line which indicates the change in $Y$ for each unit change in $X$.

The equation of the straight line trend is $Y = a + bX$

Since $\Sigma X = 0$, therefore

$$a = \frac{\Sigma Y}{N} = \frac{23335}{10} = 2333.5$$

$$b = \frac{\Sigma XY}{\Sigma X^2} = \frac{41375}{330} = 125.38$$

Thus substituting the value of '$a$' and '$b$' in the straight line of the trend, we get

$$Y = a = bX \Rightarrow Y = 2333.5 + 125.38 \times X$$

Estimate of 2025 will be calculated on the basis of $X = 29$

$$Y_{2025} = 2333.5 + 125.38 \times 29 = 71307.52$$

Table 1 shows that the Trend value of the total publications, calculated year wise. Increasing trend is seen in next 10 years of the period. The Trend value has been increased from 1205 in 2006 to 71307 in 2025.

### 4.2 Growth of Publications

Table 1 provides the AGR and CAGR of the number of publications for period 2006 to 2015.

| Year | No. of Publications Actual (Y) | Deviation | Multiply(X) | XY | X² | No. of Publications Trend |
|---|---|---|---|---|---|---|
| 2006 | 1119 | -4.5 | -9 | -10071 | 81 | 1205 |
| 2007 | 1414 | -3.5 | -7 | -9898 | 49 | 1456 |
| 2008 | 1747 | -2.5 | -5 | -8735 | 25 | 1707 |
| 2009 | 2066 | -1.5 | -3 | -6198 | 9 | 1957 |
| 2010 | 2200 | -0.5 | -1 | -2200 | 1 | 2208 |
| 2011 | 2439 | 1 | 1 | 2439 | 1 | 2459 |
| 2012 | 2741 | 1.5 | 3 | 8223 | 9 | 7377 |
| 2013 | 3081 | 2.5 | 5 | 15405 | 25 | 12294 |
| 2014 | 3171 | 3.5 | 7 | 22197 | 49 | 17212 |
| 2015 | 3357 | 4.5 | 9 | 30213 | 81 | 22130 |
| 2016 | | | 11 | | | 27048 |
| 2017 | | | 13 | | | 31965 |
| 2018 | | | 15 | | | 36883 |
| 2019 | | | 17 | | | 41801 |
| 2020 | | | 19 | | | 46719 |
| 2021 | | | 21 | | | 51636 |
| 2022 | | | 23 | | | 56554 |
| 2023 | | | 25 | | | 61472 |
| 2024 | | | 27 | | | 66390 |
| 2025 | | | 29 | | | 71308 |
| | 23335 | | | 41375 | 330 | 561781 |

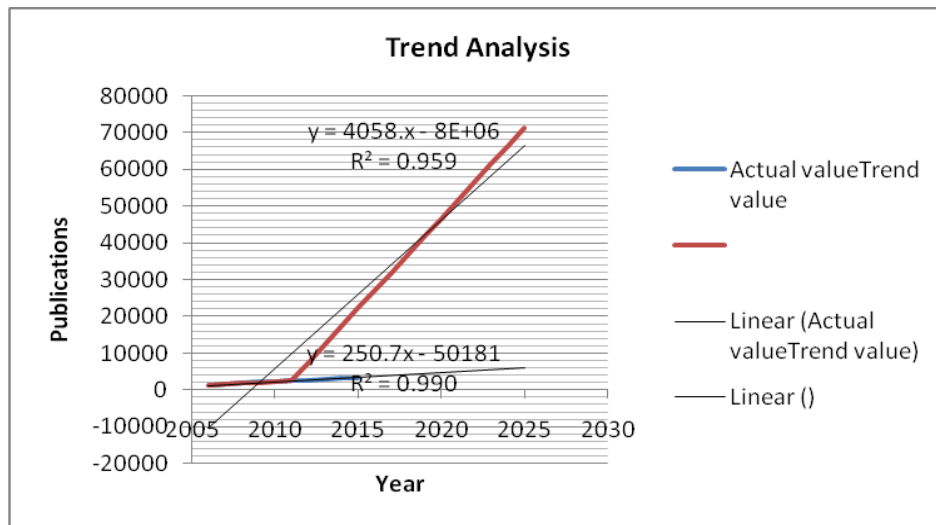Table 1. Computation of Straight Line Trend by the Least Squares Method



Figure 1. Trend of the Global warming publications

$$AGR = \frac{End\ Value\ -\ First\ Value}{First\ Value} \times 100$$

| Year | No. of publications | Cumulative total | Annual growth rate (AGR) | CAGR |
|------|---------------------|------------------|--------------------------|------|
| 2006 | 1119 | 1119 | - | - |
| 2007 | 1414 | 2533 | 126.36 | 0.7914 |
| 2008 | 1747 | 4280 | 68.97 | 0.5652 |
| 2009 | 2066 | 6346 | 48.27 | 0.4482 |
| 2010 | 2200 | 8546 | 34.67 | 0.4039 |
| 2011 | 2439 | 10985 | 28.54 | 0.3512 |
| 2012 | 2741 | 13726 | 24.95 | 0.2940 |
| 2013 | 3081 | 16807 | 22.45 | 0.2681 |
| 2014 | 3171 | 19978 | 18.87 | 0.2587 |
| 2015 | 3357 | 23335 | 16.80 | 0.2377 |

Table 2. AGR and CAGR of Publications

A total of 23335 publications were published during 2006-2015. The average number of publications per year was 2333.5. There were only 1119 publications in 2006 and a continuous growth of publications was observed during the study period. The highest total no. of publications (3357) were in 2015. It was observed that there was a steady growth of publications during 2006-2015.

The table 2 also shows that the Annual Growth Rate (AGAR) of the total publications calculated year wise. AGR reveals that it has decreased from 126.36 in 2007 to 16.80 in 2015. The compound annual growth rates of the publications are gradually decreased from 0.7914 in 2007 to 0.2377 in 2015 as seen in the table 2. This indicates that the compound annual growth rate is in down ward trend.
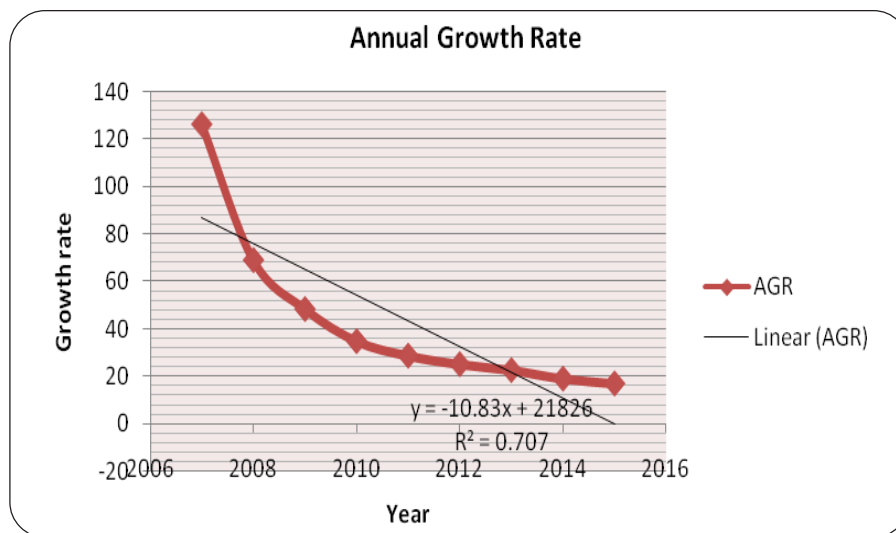


Figure 2. Annual growth rate of publications

## 4.3 Relative Growth Rate (RGR) and Doubling Time

The Relative Growth Rate (RGR) is the increase in number of articles or pages per unit of time. This definition derived from the definition of relative growth rate in the study of growth analysis in the field of global warming. The mean relative growth rate (R) over the specific period of interval can be calculated from the following equation.

Relative Growth Rate (RGR)

$1 - 2R = Log\ W_2 - Log\ W_1 / T_2 - T_1$

Whereas

$1\text{-}2\ R$ - Mean relative growth rate over the specific period of interval

$Log_e\ W_1$ - Log of initial number of articles

$Log_e\ W_2$ - Log of final number of articles after a specific period of interval

$T_2\text{-}T_1$ - The unit difference between the initial time and the final time

The year can be taken here as the unit of time.

Doubling Time (DT) = 0.693/R

| Year | No. of Publications | Cumulative Total | W1 | W2 | RGR | DT |
|------|---------------------|------------------|------|------|------|------|
| 2006 | 1119 | 1119 | - | 7.02 | - | - |
| 2007 | 1414 | 2533 | 7.02 | 7.84 | 0.82 | 0.85 |
| 2008 | 1747 | 4280 | 7.84 | 8.36 | 0.52 | 1.33 |
| 2009 | 2066 | 6346 | 8.36 | 8.76 | 0.40 | 1.73 |
| 2010 | 2200 | 8546 | 8.76 | 9.05 | 0.29 | 2.39 |
| 2011 | 2439 | 10985 | 9.05 | 9.30 | 0.25 | 2.77 |
| 2012 | 2741 | 13726 | 9.30 | 9.53 | 0.23 | 3.01 |
| 2013 | 3081 | 16807 | 9.53 | 9.73 | 0.20 | 3.47 |
| 2014 | 3171 | 19978 | 9.73 | 9.90 | 0.17 | 4.08 |
| 2015 | 3357 | 23335 | 9.90 | 10.06 | 0.16 | 4.33 |

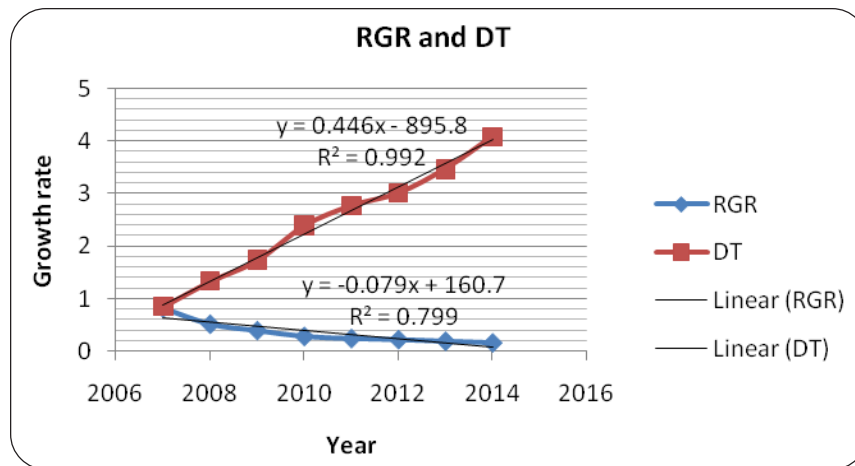Table 3. Relative growth rate (RGR) and Doubling time (DT) of publications



Figure 3. Relative growth rate for the research output

The year wise RGR is found to be in the range of 0.82 to 0.16. It has been observed from Table 3and figure 3 that RGR is downward trend from 2007 (0.82) to 2015 (0.16). The doubling time (DT) was upward trend from 2007 (0.85) to 2015 (4.33).

**4.4 Identification of Most Prolific Authors**

| Rank | Author | No. of publications | Percentage |
|------|--------|---------------------|------------|
| 1 | Anonymous | 82 | 0.35 |
| 2 | Ciais, P | 54 | 0.23 |
| 3 | Wang, B | 49 | 0.21 |
| 4 | Xie, S P | 47 | 0.20 |
| 5 | Luo, Y Q | 46 | 0.20 |
| 6 | Zhang, Y | 43 | 0.18 |
| 7 | Kumar, A | 42 | 0.18 |
| 8 | Zhou, T J | 42 | 0.18 |
| 8 | Li, Y | 41 | 0.18 |
| 10 | Christensen, T H | 40 | 0.17 |

Table 4. Identification of most prolific authors

The authors having 40 or more publications during 2006-2015 are listed in the table 4. Anonymous is the most productive author with 82 (0.35%) publications followed by Ciais, P with 54 (0.23%) publications, Wang, B with 49 (0.21%) publications, Xie, S P with 47 (0.20%) publications, Luo, Y Q with 46 (0.20%) publications, Zhang, Y with 43 (0.18%) publications, Kumar, A with 42 (0.18%) publications and Zhou, T J with 42 (0.18%) publications respectively. And a total of 56,533 authors are contributed entire research output of the period under study.
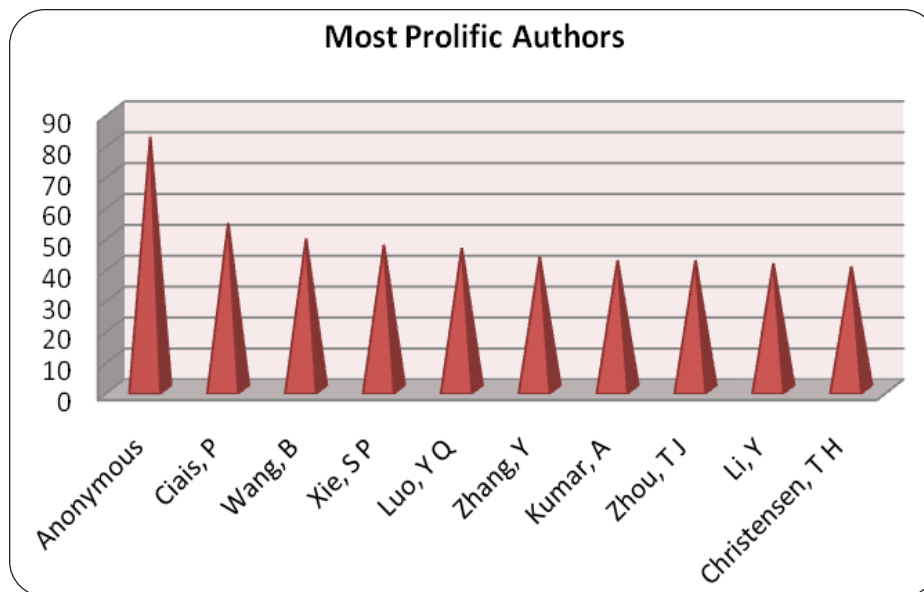


Figure 4. Most prolific authors

### 4.5 High Productive Institutes

| Rank | Institutions | Country | No. of Publications |
|------|-------------|---------|---------------------|
| 1 | Chinese Academy of Science | China | 1298 (5.56%) |
| 2 | National Oceanic and Atmospheric Administration | USA | 424 (1.82%) |
| 3 | National Centre for Atmospheric Research | USA | 350 (1.50%) |
| 4 | Columbia University | USA | 337 (1.44%) |
| 5 | National Aeronautics Space Administration | USA | 321 (1.38%) |
| 6 | University of Washington | USA | 308 (1.32%) |
| 7 | University of Colorado | USA | 303 (1.30%) |
| 8 | University of Tokyo | Japan | 278 (1.19%) |
| 9 | University of California, Berkeley | USA | 262 (1.12%) |
| 10 | Russian Academy of Science | Russia | 247 (1.06%) |

Table 5. High productive institutes

Table 5 presents the top 10 institutes that have contributed 240 or more publications on global warming during 2006-2015. A total of 11,386 institutions are contributed entire research output of the study. Among these top 10 institutions 8 are from USA and each one from China, Japan and Russia. Chinese Academy of Science, China topped the list with 1298 (5.56%) publications followed by National Oceanic and Atmospheric Administration, USA with 424 (1.82%) publications, National Centre for Atmospheric Research, USA with 350 (1.50%) publications, Columbia University, USA with 337 (1.44%) publications, National Aeronautics Space Administration, USA with 321 (1.38%) publications, University of Washington, USA with 308 (1.32%) publications, University of Colorado, USA with 303 (1.30%) publications and University of Tokyo, Japan with 278 (1.19%) publications.

### 4.6 High Productive Countries

| Rank | Country | Total Publications (%) | Rank | Country | Total Publications (%) |
|------|---------|------------------------|------|---------|------------------------|
| 1 | USA | 7908 (33.89%) | 10 | Italy | 880 (3.77%) |
| 2 | China | 2939 (12.59%) | 11 | Netherlands | 783 (3.36%) |
| 3 | England | 2382 (10.21%) | 12 | India | 758 (3.25%) |
| 4 | Germany | 2133 (9.14%) | 13 | Switzerland | 735 (3.15%) |
| 5 | Australia | 1632 (6.70%) | 14 | Sweden | 708 (3.03%) |
| 6 | France | 1476 (6.33%) | 15 | Norway | 663 (2.84%) |
| 7 | Japan | 1466 (6.28%) | 16 | South Korea | 570 (2.44%) |
| 8 | Canada | 1403 (6.01%) | 17 | Denmark | 549 (2.35%) |
| 9 | Spain | 1085 (4.65%) | | | |

Table 6. High productive countries

In all, there were 141 countries involved in the research on global warming. The publications share of high productive countries (e"500 publications) in global warming varies from 2.35% to 33.89% as seen in the table 5 and figure 5. USA topped the list with highest share 7908 (33.89%) of publications. China ranked second with 2939 (10.21%) share of publications followed by England 2382 (10.21%) share of publications, Germany with 2133 (9.14%) share of publications, Australia with 1632 (6.70%) share of publications, France with 1476 (6.33%) share of publications, Japan with 1466 (6.28%) share of publications, Canada with 1403 (6.01%) share of publications and Spain with 1085 (4.65%) share of publications and the remaining countries are publishing less than 4% of the research output. However, USA and China together accounts for 46% of world global warming research publications. India ranks 12th among the countries publishing global warming publications.
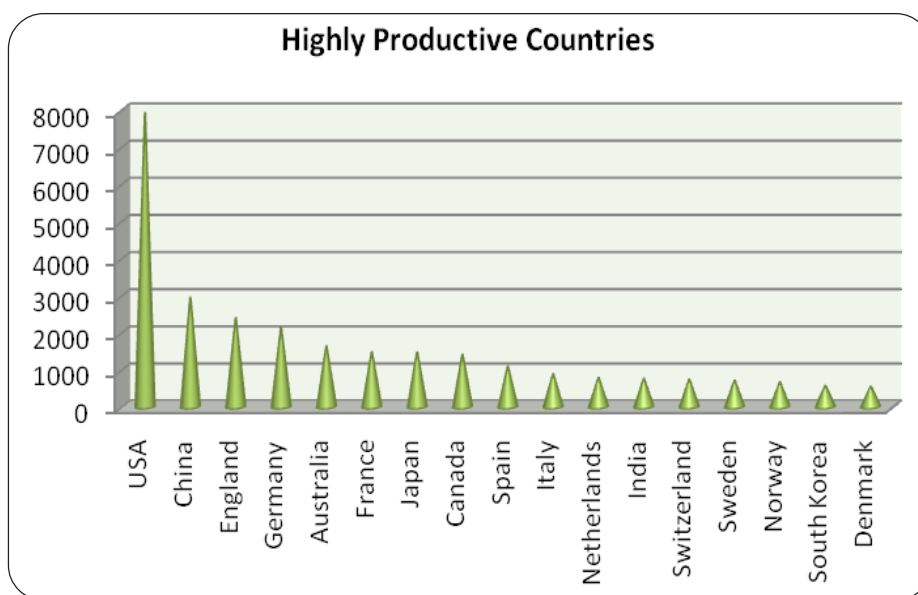


Figure 4. Highly productive countries

**4.7 Language wise Distributions**

| Rank | Language | No. of Publications |
|------|----------|---------------------|
| 1 | English | 23012 (98.62%) |
| 2 | Chinese | 61 (0.26%) |
| 3 | French | 51 (0.22%) |
| 4 | Spanish | 49 (0.21%) |
| 5 | German | 43 (0.18%) |
| 6 | Japanese | 29 (0.12%) |
| 7 | Portuguese | 26 (0.11%) |
| 8 | Polish | 13 (0.06%) |
| 9 | Turkish | 10 (0.04%) |
| 10 | Croatian | 8 (0.03%) |

Table 7. Language wise distribution of publications

Publications on global warming are spread over 23 languages. The study reveals that the maximum number of publications have been published in English language with 23012 (98.62%) publications, followed by Chinese language with 61 (0.26%) publications, French language ranks third position with 51 (0.22%) publications, Spanish language with 49 (0.21%) publications, German language with 43 (0.18%) publications, Japanese language with 29 (0.12%) publications and Portuguese language with 26 (0.11%) publications. The most predominant language used for the research output is English in every year in the total productivity on the subject during the study period.

## 4.8 Most Preferred Source Titles

| Rank | Source Title | No. of Publications | Percentage | Impact Factor |
|---|---|---|---|---|
| 1 | Journal of climate | 717 | 3.07 | 4.45 |
| 2 | Geophysical research letters | 625 | 2.68 | 4.99 |
| 3 | Global change biology | 507 | 2.17 | 8.44 |
| 4 | Journal of geophysical research atmospheres | 418 | 1.79 | 3.32 |
| 5 | Climate dynamics | 409 | 1.75 | 4.71 |
| 6 | PLOS one | 319 | 1.37 | 3.06 |
| 7 | Climatic change | 316 | 1.35 | 3.34 |
| 8 | Proceedings of the national academy of sciences of the USA | 284 | 1.22 | 9.42 |
| 9 | Environmental research letters | 262 | 1.12 | 3.91 |
| 10 | Journal of cleaner production | 242 | 1.04 | 5.84 |

Table 8. Source Title of Publications

Table 8 presents the leading journals each with number of publications and impact factor. The scientific literature on global warming is spread over 3297 different web of science source journals. It reveals that Journal of climate top the list with the highest number of publications 717 (3.07%) and the impact factor is 4.45, followed by Geophysical research letters with a share of 625 (2.68%) publications and the impact factor is 4.99. Global change biology occupies the third position with 507 (2.17%) publications and the impact factor is 8.44. The fourth highest source title is Journal of geophysical research atmospheres with 418 (1.79%) publications and the impact factor is 3.32, Climate dynamics with 409 (1.75%) publications and the impact factor is 4.71 and PLOS one with 319 (1.37%) publications and the impact factor is 3.06.

## 4.9 High Productivity Subject Areas
The scientific literature on global warming is spread over 119 different subjects. Table 8 shows 10 high productivity subjects which are contributing more than 900 articles. It is found that Environmental sciences ecology has highest number of articles with 6872 (29.45%) followed by Meteorology atmospheric sciences contributing 4474 (19.17%) articles. Geology occupies the third position with 3181 (13.63%) articles. The fourth highest articles belonged to the subject Engineering with 2580 (11.06%), Science and technology with 1506 (6.45%) and Agriculture with 1347 (5.77%) articles respectively.

## 5. Summary and Conclusions

The present study attempted to highlight the growth and development of research output on global warming. A total of 23335 publications were published during 2006-2015 and the average number of publication per year was 2333.5. There was a steady growth of publication during the study period. USA topped the list with highest share (33.89%) of publications followed by China with 12.59% share of publications, England with 10.21% share of publications and Germany with 9.14% share of publications. Chinese Academy of Science, China topped the list with 1298 (5.56%) publications followed by National Oceanic and Atmospheric

| Rank | Subject | No. of Articles | Percentage |
|---|---|---|---|
| 1 | Environmental sciences and ecology | 6872 | 29.45 |
| 2 | Meteorology atmospheric sciences | 4474 | 19.17 |
| 3 | Geology | 3181 | 13.63 |
| 4 | Engineering | 2580 | 11.06 |
| 5 | Science and technology | 1506 | 6.45 |
| 6 | Agriculture | 1347 | 5.77 |
| 7 | Energy fuels | 1335 | 5.72 |
| 8 | Physical geography | 1002 | 4.29 |
| 9 | Marine freshwater biology | 923 | 3.96 |
| 10 | Oceanography | 900 | 3.96 |

Table 9. High productivity subject areas

Administration, USA with 424 (1.82%) publications, National Centre for Atmospheric Research, USA with 350 (1.50%) publications, and Columbia University, USA with 337 (1.44%) publications. The most prolific authors, high productive subjects and also the most preferred journals with impact factor which they publish have also been identified. It is to note that the India is also substantially contributed for the literature growth.

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