

# A bibliometric study of the world's research activity in sustainable development and its sub-areas using scientific literature

Saeed-Ul Hassan · Peter Haddawy · Jia Zhu

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**Abstract** This paper presents a bibliometric study of the world's research activity in Sustainable Development using scientific literature. The study was conducted using data from the Scopus database over the time period of 2000–2010. We investigated the research landscape in Sustainable Development at country level and at institute level. Sustainable Development and its sub-areas are defined by keywords vetted by the domain experts, allowing publications to be identified independent of the journals and conferences in which they are published. The results indicate that institutes strong in Sustainable Development overall may not be strong in all sub-areas and that institutes not strong in Sustainable Development overall may have significant niche strengths in a given sub-area. It is also noted that China appears strong in terms of publication output in Sustainable Development and its sub-areas but it does not appear strong in terms of citation counts. The information produced in this study can be useful for government research agencies in terms of understanding how to more effectively knit together the various niche strengths in the country; and for the institutes to find strategic partners that can coordinate in niche areas of Sustainable Development and complement their strengths. In order to conduct bibliometric analysis in an interdisciplinary research area, the keyword collection approach appears to be very useful. This approach is flexible and can be used to conduct such analysis for interdisciplinary research fields.

**Keywords:** Bibliometrics · Sustainable development · Interdisciplinary research fields

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S.-U. Hassan (✉)  
COMSATS Institute of Information Technology, Lahore, Pakistan  
e-mail: saeedulhassan@gmail.com

P. Haddawy  
Mahidol University, Phuttamonthon 4 Road, Nakhon Pathom 73170, Thailand

J. Zhu  
School of Computer Science, South China Normal University, Guang Zhou, China

## Introduction

### Sustainable development overview

Increasing attention is being focused on the topics of “Sustainability” and “Sustainable Development” by policy makers and by the scientific research community. Sustainable Development concerns various aspects including nature (e.g., climate, ocean, rivers, plants, and other components of the natural environment), artefacts (e.g., machinery, chemicals, biotechnology, materials, and Renewable Energy), and society (e.g., economy, industry, finance, demography, culture, ethics, and history) (Lele 1991; Goodland 1995; Christensen et al. 1996). Though the concept of sustainability has a long history dating back to Malthus (1830) and Mill (1900), it has not been seen as a high priority area of research until more recently (Haberli and Klein 2001).

In recent years, Sustainable Development and its various sub-areas such as Renewable Energy and Climate Change have been declared as national priority areas by many countries and international organizations. In December 2002, the United Nations General Assembly, through its resolution 57/254, declared 2005–2014 as a Decade of Education for Sustainable Development (DESD). UNESCO, the leading agency for DESD, seeks to integrate the principles, values, and practices of Sustainable Development into all aspects of education and learning. Activities under DESD seek to address the social, economic, cultural and environmental problems that we have faced in the twenty-first century (IIS 2004). The concepts of Sustainable Development and Sustainable Human Development also deeply resonate with the Millennium Development Goals (MDGs) (<http://www.un.org/millenniumgoals/>). The eight MDGs focus mainly on reducing poverty, meeting basic human wants and needs, fulfilling human rights (including basic education and gender equality) and integrating Sustainable Development into country policies and programmes. Moreover, the Intergovernmental Panel on Climate Change (IPCC) has emphasized the two-way relationship between Climate Change mitigation and Sustainable Development on their Fourth Assessment Report (AR4) released in 2007 (Munasinghe 2007).

An increasing number of institutes have begun to adopt Sustainable Development as a strategic research focus and some have even established schools and degree programs for sustainability. For example, Arizona State University established School of Sustainability in spring 2007 as part of Global Institute of Sustainability (<http://sustainability.asu.edu/>) and the University of Tokyo has programs in Sustainability Science. Hokkaido University (<http://www.sustain.hokudai.ac.jp/>) has taken an initiative called “Hokudai Network for Global Sustainability” to create a network of research and higher education institutions for Global Sustainability; Rikkyo University (<http://www.rikkyo.ac.jp/>) has launched the Education for Sustainable Development Research Center (ESDRC); and Osaka University has launched a new trans-disciplinary research organization, the Research Institute for Sustainability Science (RISS) (Uwasu et al. 2009).

Given the recognized critical need for countries to develop more Sustainable Development paths and the rapid increase in resources now being invested in this area, it becomes important to clearly understand the current state of research activity in this area. This paper aims to investigate the world’s research landscape in Sustainable Development and its sub-areas. The quantitative bibliometric analyses are well suited to investigate such research trends. However, conducting such analyses in highly interdisciplinary and emerging areas like Sustainable Development is highly challenging.

## Sustainable development and bibliometric analysis

Bibliography database resources use journal/conference-proceedings mappings with pre-defined categories for organizing resources in the database. For instance, Thomson Reuters' ISI Web of Science (WoS) assigns ISI subject categories to all indexed source journals and conference proceedings (Leydesdorff and Rafols 2009). Also, Scopus utilizes All Science Journal Classification (ASJC) to map source titles in structured hierarchy of disciplines and sub-disciplines. However, the use of such journal classification is not well suited to conduct bibliometrics analysis in interdisciplinary and emerging areas (Pudovkin and Garfield 2004; Leydesdorff and Opthof 2010). Few journals exist for the field of Sustainable Development, so that papers are published mainly in journals of other disciplines. Assigning all these journals of other disciplines to Sustainable Development can result in the false classification of many nonrelated papers under the field of Sustainable Development; and assigning few of these journals to Sustainable Development can lead to missing many related articles.

In general, bibliometric analyses of research activity in interdisciplinary areas like Sustainable Development procure scientific literature by using the two approaches: one is searching for simple terms like “sustainability” or “sustainable” in the titles, abstracts and keywords and the other is using a collection of keyword terms. Our present work extends the second approach and seeks to build a rich collection of terms representing the field of Sustainable Development and its sub-areas (Kajikawa et al. 2007; Yarime et al. 2010; Quental and Lourenco 2012; Li and Dora 2013; Yang et al. 2013; Hassan et al. 2012).

Sustainable Development is highly interdisciplinary in nature and yet evolving; therefore it has been a matter of debate as to what should be included in the field. There have been efforts to provide a research core and framework of Sustainable Development by identifying sub-areas of Sustainable Development through bibliometric analysis (Kajikawa 2008). In particular, using topological clustering, Kajikawa et al. (2007) identify the following sub-areas of sustainability science: Agriculture, Fisheries, Ecological Economics, Forestry (tropical rain forest, biodiversity, agroforestry), Business, Tourism, Water, Urban Planning, Rural Sociology, Renewable Energy, Health, Soil and Wildlife; and common topics, Education, Biotechnology, Medical, Livestock, Climate Change, Welfare, and Livelihood. Furthermore, a number of taxonomies have been proposed that differ in the concepts included and their grouping into subject areas. Here we discuss some of the most prominent taxonomies and examine their commonalities and differences. United Nation Department of Economic and Social Affairs, Division for Sustainable Development (UNDESA) lists 28 Sustainable Development topics grouped in two main categories i.e. Social & Economic and Natural Resource Management.<sup>1</sup> While The World Bank classifies Sustainable Development topics into 10 main categories<sup>2</sup> (<http://web.worldbank.org/>), the Organization for Economic Co-operation and Development (OECD) classifies Sustainable Development topics into 13 categories<sup>3</sup> (see Table 5 in Appendix 1 for details).

<sup>1</sup> <http://web.archive.org/web/20110604195301/> [http://www.un.org/esa/dsd/susdevtopics/sdt\\_index.shtml](http://www.un.org/esa/dsd/susdevtopics/sdt_index.shtml), retrieved 4-June-2011.

<sup>2</sup> <http://web.archive.org/web/20111022034846/> <http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTSDNET/0,contentMDK:22180649~menuPK:64885123~pagePK:64885161~piPK:64884432~theSitePK:5929282,00.html>, retrieved 22-Oct-2011.

<sup>3</sup> <http://web.archive.org/web/20110209105820/> [http://www.oecd.org/topic/0,3699,en\\_2649\\_37425\\_1\\_1\\_1\\_1\\_37425,00.html](http://www.oecd.org/topic/0,3699,en_2649_37425_1_1_1_1_37425,00.html), retrieved 9-Feb-2011.

To select Sustainable Development topics for inclusion in the current study, we sought to identify areas of agreement among the taxonomies. Agriculture, Water, Climate Change, Transport and Biodiversity are common topics among the World Bank, OECD, and UNDESA taxonomies. Fisheries is the common topic between the World Bank and OECD. Rural Development, Renewable Energy and Forestry are common topics between UNDESA and OECD. While Urban Development only appears in the World Bank taxonomy, this topic also appears in Sustainable Development taxonomy based on citation analysis. We also chose to include Urban Development from the World Bank taxonomy in order to provide symmetric coverage since Rural Development has been included. We have chosen to also include Waste, which appears in the UNDESA taxonomy and is a major area of interest in UNEP's Green Economy Report.<sup>4</sup> Figure 1 shows Sustainable Development topics covered by the selected taxonomies. The topics shown in grey background are the ones selected to be included in the current study: Agriculture, Biodiversity, Climate Change, Renewable Energy, Fisheries, Forestry, Rural Development, Urban Development, Sustainable Production & Consumption, Transport, Water and Waste.

## Data collection and methodology

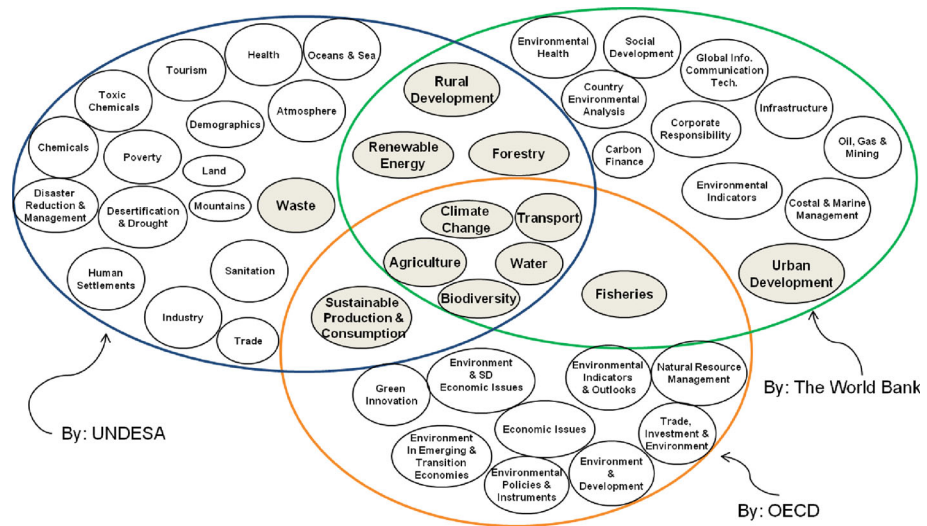
### Bibliography dataset for the sub-areas of sustainable development

We identified the keyword queries for each sub-area and then used these queries to pull related scientific literature from the bibliography database. The keywords associated with a given sub-area of Sustainable Development are specific to work in that area. This is needed for two reasons. First we must be able to identify publications in each of the sub-areas. Second, publications specific to a sub-area of Sustainable Development may not mention terms like “sustainable” or “sustainability”, so a query to retrieve all publications in Sustainable Development must contain these field-specific terms such as “organic photovoltaics” which is relevant to Renewable Energy. Using this bottom up approach, we are then able to procure relevant set of publications in the area of Sustainable Development and its sub-areas.

The followings are the steps to obtain keyword query for a given sub-area of Sustainable Development. Step-1: First we contacted relevant domain experts<sup>5</sup> in the field to provide a list of keywords related to the sub-area under consideration (we called them seed keywords). Step-2: We use the seed keywords query to procure publications with keywords in the query matched against keywords in the title, author defined keywords and abstracts. A part of the query to pull the publications related to Climate Change would be as follows: (“*climatic changes*” OR “*climate warming*” OR “*climate change*” OR “*kyoto protocol*” OR “*paleoclimate*” OR “*global climate change*” OR “*climate variability*” ...). Step-3: We then identify the co-occurred author defined keywords from the procured publications and add them to the initial seed keywords in the query. Step-4: We repeat Step-2 and Step-3 to obtain rich collection of keywords to define the sub-area under consideration. We present these keywords to relevant domain experts (in each iteration) to help us to exclude irrelevant keywords from the query. We repeat the Step-4 until there are no new keywords found related to the sub-area under consideration. Some keywords which have field-

<sup>4</sup> <http://www.unep.org/greeneconomy/GreenEconomyReport/tabid/29846/Default.aspx>, retrieved 21-Jan-2012.

<sup>5</sup> The list of domain experts is presented in Appendix 2.



**Fig. 1** Sustainable Development taxonomies by The World Bank, UNDESA and OECD

specific meanings in Sustainable Development can have additional meanings in other fields, so these are “ANDed” with (“sustainable” OR “sustainability”) to restrict their meaning. In addition, some keywords are “ANDed” with a set of source titles in order to limit the scope of publications in the sub-area. The experts also include some keywords which do not appear in final keywords collection but are relative to the sub-area under consideration.

The query for Sustainable Development overall is then taken to be the union of all keywords for the selected sub-areas along with the general keywords for Sustainable Development i.e. “sustainable” or “sustainability”. We take union of all keywords of the sub-areas since identified sub-areas can overlap with each other. The lists of keywords for the sub-areas of Sustainable Development are shown in Appendix 3.

Finally, the retrieval is performed on the Scopus database to procure publications with keywords in the query matched against keywords in the title, list of author defined keywords and abstracts. With the term publication, we refer to scientific publications in acknowledged scientific journals, or conference proceedings, like articles, reviews and conference papers.

In this paper, we study the research landscape of Sustainable Development at the country level and at the institute level. At the country level, we examine research activities of countries in the world which have the highest number of publications in each selected sub-area of Sustainable Development during year 2000–2010. At the institute level, we examine the distribution of research strengths of institutions in the sub-areas of Sustainable Development. The current study presents the analysis of top fifteen institutions<sup>6</sup> which have highest number of publications in Sustainable Development and its sub-areas during year 2000–2010.

<sup>6</sup> In Scopus database, institutions may have more than one Affiliation ID due to their name variations. Therefore, in order to correctly procure the papers published by a given institute, we first combine the Scopus Affiliation IDs of all those institutes that have more than one Affiliation ID in Scopus.

## Bibliometric indicators used in this study

At the country level we examine the research activity of countries in terms of their publication output in Sustainable Development and its sub-areas. Then research strengths of internationally reputed institutions are investigated. We analyze research strengths in terms of absolute publication counts, citation counts and citations per paper (CPP). While absolute number of publication and citation counts provided actual research output and impact, CPP provides a way to measure the scholarly impact of research per publication. The CPP is calculated by taking the following ratio: “total citations received by the papers in a given sub-area of Sustainable Development during a given time window published during the same time window” to “total number of papers in the sub-area of Sustainable Development published during a given time window”.

For graphs of trends over time, a sliding time window is utilized to capture publication activity and to smooth small random variations from year to year in order to better highlight important trends. To determine this time window, we computed the median citation half-life of scientific articles in Sustainable Development, which turns out to be 6 years. Consequently, we utilize 6-year sliding windows to plot the publication output and citation counts, e.g. papers published in 2005 get 6 years citation time including publication year.

## Result and Discussion

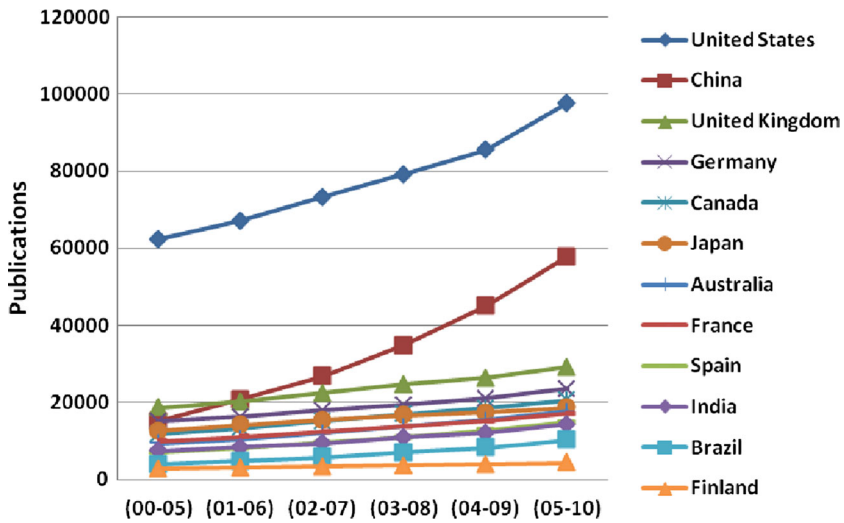
### Publication output of countries in sustainable development and its sub-areas

This section presents the results of publication output of countries in Sustainable Development and its sub-areas. We discuss the results of Sustainable Development overall along with the three important sub-areas i.e. Climate Change, Renewable Energy and Forestry. The results for the remaining sub-areas are presented in Appendix 1 Table 6.

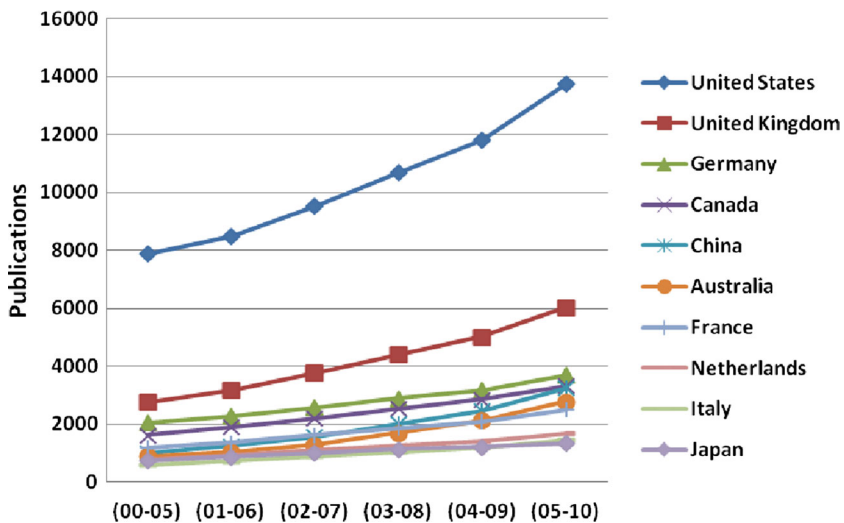
Figure 2 shows top ten countries in terms of publication output in Sustainable Development during 2000–2010. While the United States is clearly leading in terms of publication output in Sustainable Development, China takes 2nd rank in terms of publications. We find a big gap between the United States and, China followed by a big gap between China and rest of the selected countries. The results indicate that China has significantly increased its publication output in Sustainable Development in recent years. We further analyzed research strengths of countries in sub-areas of Sustainable Development. This helps us to understand different focus of countries towards the areas in Sustainable Development.

Figure 3 shows publication output of top ten countries in the sub-area Climate Change during 2000–2010. In Climate Change, the United States again shows significant research strengths followed by the United Kingdom, Germany, Canada and China. Relative to total publication output in Sustainable Development, the United Kingdom shows the highest proportion of its publication in Climate Change during 2005–2010 i.e. 20.60 %, followed by Canada (16.1 %), Germany (15.74 %), Australia (15.66 %), the United States (14.08 %) and China shows only 5.6 % of its publications output in Climate Change.

Figure 4 shows publication output of top ten countries in the sub-area Renewable Energy during 2000–2010. The picture looks rather different from the research strengths of the countries in Climate Change. With regard to Renewable Energy, the United States and China are close in terms of publication output in recent years, followed by Japan, Germany



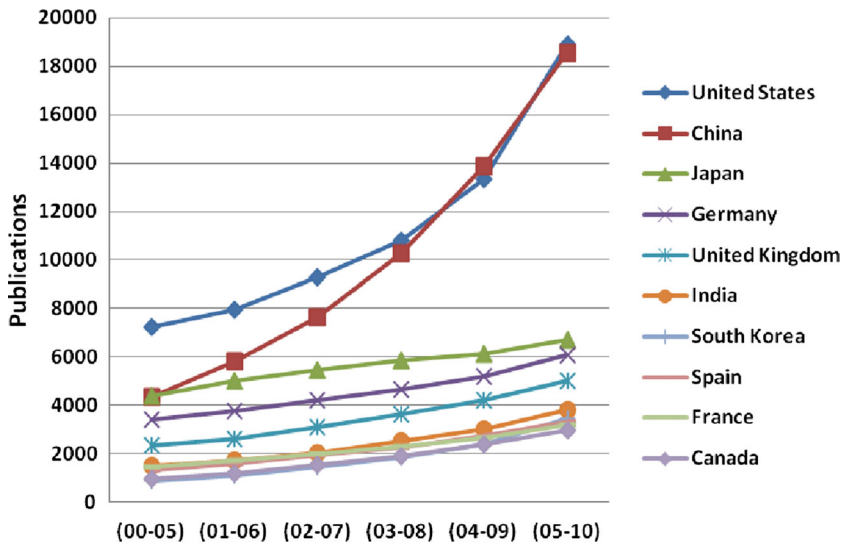
**Fig. 2** Research strengths of top ten countries in terms of publication output in Sustainable Development during 2000–2010



**Fig. 3** Research strengths of top ten countries in terms of publication output in the sub-area Climate Change during 2000–2010

and the United Kingdom. Relative to total publication output in Sustainable Development, China shows a significant proportion of its publication in sub-area Renewable Energy during 2005–2010 i.e. 31.11 %, followed by Germany (25.87 %).

The significant focus of the Chinese researchers in the areas of Renewable Energy may indicate the outcomes of Chinese Government policies and initiatives, considering energy resources as one of China’s priority areas of S&T (Nathaniel and Jonathan 2006). This can be evidenced by the fact that the total investment alone in the area of Renewable Energy in



**Fig. 4** Research strengths of top ten countries in terms of publication output in the sub-area Renewable Energy during 2000–2010

2007 has been recorded US\$12 billion Kinver (2008). Consequently, China is world's leading Renewable Energy producer now, with the largest wind turbines and solar panels producer (Bradsher, 2010) and has an installed capacity of 152 GW (Alok, 2011; Callum, 2010).

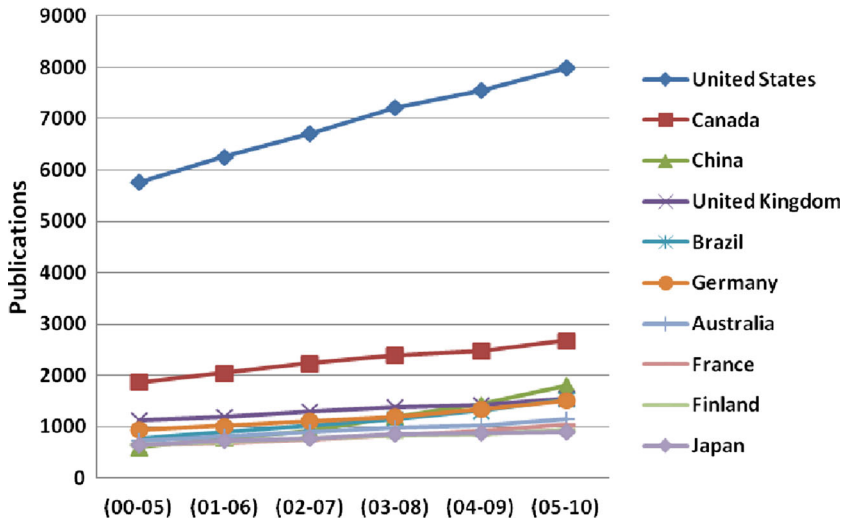
Figure 5 shows publication output of top ten countries in the sub-area Forestry during 2000–2010. Canada is strong in terms of its publication output in the sub-area, only second to the United States. Interestingly, Finland makes its position among the top ten publishing countries in the world in the sub-area Forestry, despite the fact Finland is ranked 115th in terms of its total population in the world. Relative to total publication output in Sustainable Development. Finland shows the highest proportion of its publication in the sub-area Forestry during 2005–2010 i.e. 21.48 %, followed by Brazil (14.91 %), Canada (12.95 %), Australia (6.53 %), Germany (6.4 %) and China shows only 3.14 % of its publications output in Forestry.

#### Research strengths of institutes in sustainable development and its sub-areas

At the institute level, we analyze the research strengths of the top 15 institutions from all over the world in terms of publication output in Sustainable Development and its sub-areas during 2005–2010. We discuss the results of overall Sustainable Development along with the three important sub-areas i.e. Climate Change, Renewable Energy and Forestry. The results for the remaining sub-areas are presented in Appendix 1 Table 7.

Table 1 shows publication and citation counts along with the CPP of the selected institutions in Sustainable Development. The result indicates that Chinese Academy of Science (CAS) is ranked 1st in terms of publication output, followed by Tsinghua University and UC Davis. In terms of citations counts, UC Berkeley shows the highest





**Fig. 5** Research strengths of top ten countries in terms of publication output in the sub-area Forestry during 2000–2010

**Table 1** Research strengths of top 15 institutions from all over the world in terms of publication output in Sustainable Development during 2005–2010

Institute	Country	Pubs	Cites	CPP
UC Berkeley	United States	2,236	24,103	10.78
University of Washington Seattle	United States	1,837	18,257	9.94
UC Davis	United States	2,255	16,985	7.53
The University of British Columbia	Canada	1,947	16,146	8.29
Pennsylvania State University	United States	1,613	15,950	9.89
University of Wisconsin Madison	United States	1,724	15,687	9.1
United States Geological Survey	United States	1,767	14,622	8.28
Chinese Academy of Sciences	China	3,686	13,372	3.63
University of Florida	United States	2,194	12,676	5.78
University of Tokyo	Japan	1,919	10,716	5.58
Texas A and M University	United States	1,702	9,959	5.85
USDA Agricultural Research Service, Washington DC	United States	1,668	9,707	5.82
Tsinghua University	China	2,992	8,271	2.76
Universidade de Sao Paulo	Brazil	1,848	7,581	4.1
Zhejiang University	China	2,024	5,826	2.88

strengths, followed by University of Washington Seattle and UC Davis. Note that the Chinese institutes show low CPP values among the selected institutes.

Table 2 shows publication and citation counts along with the CPP of the selected institutions in Climate Change. The US National Oceanic and Atmospheric Administration is ranked 1st in terms of publication output, followed by CAS, University of Colorado at Boulder and the US National Center for Atmospheric Research. In terms of citation counts

and CPP, the US National Center for Atmospheric Research shows the highest strengths. While CAS is strong in terms of publication output, it does not appear strong in terms of citations counts. In Climate Change, the research landscape of the United State is significantly supported by the research institutions as a large proportion of publications and citations is contributed by the research institutions.

In the sub-area Renewable Energy, Tsinghua University is ranked 1st in terms of publication output, followed by the US National Renewable Energy Laboratory and CAS (see Table 3). In terms of citation counts, the US National Renewable Energy Laboratory is ranked 1st followed by Imperial College London, Pennsylvania State University and National Institute of Advanced Industrial Science and Technology, Japan. While Tsinghua University shows highest publication output, it does not appear strong in terms of CPP.

In the sub-area Forestry, USDA Forest Service, United States is ranked 1st in terms of publication output, followed by the Swedish University of Agricultural Sciences and Helsingin Yliopisto, Finland (see Table 4). The Smithsonian Tropical Research Institute, United States is the strongest in terms of CPP value followed by University of Wisconsin, Madison. Interesting, we find couple of Finnish institutions among the top tier institutes that shows the research focus of Finland in Forestry. Note that the Finnish institutes do not show up among the top tier institutions in Sustainable Development overall but they appear among the top tier institutions in Forestry.

## Summary and concluding remarks

In this paper, we presented bibliometric study of world's research activity in Sustainable Development using Scopus database over the time period of 2000–2010. We investigated the research strengths in Sustainable Development and its sub-areas at country level and at institute level. The present study has generated a large amount of empirical data and information related to research performance of countries and institutions in Sustainable Development and is summarized as follows:

- In Sustainable Development overall, the United States leads in research. Among the Asian countries, Chinese institutions are ahead in publications and citations in Sustainable Development and its sub-areas.
- In Climate Change, the United Kingdom shows significant research focus this sub-area. Relative to total publication output in Sustainable Development, China shows only a small proportion of its publications output in Climate Change. At the institute level, Chinese institutions appear strong in terms of publication output. However, they do not show up on high scale in terms of scholarly impact per paper.
- In Renewable Energy, China shows significant research focus in the sub-area. At the institute level, Chinese institutions again appear strong in terms of publication output but do not appear strong in terms of citation counts. In Forestry, Finland shows significant research focus the sub-area, followed by Brazil. At the institute level, we do not find Chinese institutes among the top tier institutions in Forestry.
- In Rural Development, the United States is strong with most of the top tier institutions in the area are from the United States. We also find Wageningen University from Netherland among the top tier universities in the field. In Urban Development, The University of Hong Kong and Delft University of Technology, Netherlands are also among the top tier universities along with some Chinese and North American institutions.

**Table 2** Research strengths of top 15 institutions from all over the world in terms of publication output in the sub-area Climate Change during 2005–2010

Institute	Country	Pubs	Cites	CPP
National Center for Atmospheric Research	United States	539	11,555	21.44
National Oceanic and Atmospheric Administration	United States	667	11,193	16.78
University of Colorado at Boulder	United States	576	8,211	14.26
Met Office	United Kingdom	441	7,699	17.46
University of Oxford	United Kingdom	453	7,245	15.99
University of Washington Seattle	United States	515	6,839	13.28
NASA Goddard Space Flight Center	United States	477	6,802	14.26
CNRS Centre National de la Recherche Scientifique	France	449	6,179	13.76
University of East Anglia	United Kingdom	428	6,043	14.12
UC Berkeley	United States	370	5,327	14.4
University of Reading	United Kingdom	351	5,062	14.42
United States Geological Survey	United States	336	4,325	12.87
University of Arizona	United States	334	3,823	11.45
Chinese Academy of Sciences	China	603	2,900	4.81
Russian Academy of Sciences	Russian Federation	325	1,685	5.18

**Table 3** Research strengths of top 15 institutions from all over the world in terms of publication output in the sub-area Renewable Energy during 2005–2010

Institute	Country	Pubs	Cites	CPP
National Renewable Energy Laboratory	United States	1,205	9,984	8.29
UC Berkeley	United States	419	6,894	16.45
Imperial College London	United Kingdom	531	6,232	11.74
Pennsylvania State University	United States	417	5,818	13.95
National Institute of Advanced Industrial Science and Technology	Japan	618	4,470	7.23
Tsinghua University	China	1,336	4,100	3.07
Chinese Academy of Sciences	China	730	3,259	4.46
Delft University of Technology	Netherlands	482	2,842	5.9
Fraunhofer-Institut für Solare Energiesysteme	Germany	418	2,579	6.17
University of Tokyo	Japan	515	2,573	5
Zhejiang University	China	587	1,587	2.7
Tianjin University	China	560	1,444	2.58
Shanghai Jiaotong University	China	578	1,281	2.22
Harbin Institute of Technology	China	527	1,087	2.06
Huazhong University of Science and Technology	China	464	1,024	2.21

**Table 4** Research strengths of top 15 institutions from all over the world in terms of publication output in the sub-area Forestry during 2005–2010

Institute	Country	Pubs	Cites	CPP
USDA Forest Service	United States	767	4,832	6.3
Smithsonian Tropical Research Institute	United States	275	3,399	12.36
Swedish University of Agricultural Sciences	Sweden	474	3,294	6.95
Helsingin Yliopisto	Finland	417	3,272	7.85
Oregon State University	United States	359	2,801	7.8
The University of British Columbia	Canada	364	2,554	7.02
Canadian Forest Service	Canada	354	2,531	7.15
UC Berkeley	United States	274	2,376	8.67
University of Wisconsin Madison	United States	232	2,332	10.05
University of Alberta	Canada	341	2,323	6.81
University of Florida	United States	314	1,979	6.3
Finnish Forest Research Institute	Finland	342	1,843	5.39
Universidade de Sao Paulo	Brazil	315	1,719	5.46
USDA Forest Service Pacific Northwest Research Station	United States	267	1,368	5.12
Universität Göttingen	Germany	242	1,296	5.36

- In Sustainable Agriculture, Brazil is among the top tier countries. In Fisheries, Australia, Canada and the United Kingdom are strong along with the United States. University of Cape Town, South Africa is among the top tier institutions in Fisheries.
- In Sustainable Production and Consumption, European institutions show significant research strengths with nine institutions out of fifteen are from the Europe: The Technical University of Denmark, The Royal Institute of Technology (KTH), ETH Zurich, Norwegian University of Science and Technology, Lunds University, Leiden University, Delft University of Technology, University of Surrey and Chalmers University of Technology.

Based on the analyses conducted at various levels and the information we gain, the following points can be concluded:

1. The United States shows significant research strengths in Sustainable Development and its sub-areas.
2. In Asia, China shows high publication output in Sustainable Development overall and its sub-areas. China's large publication volume is supported by the large Chinese research community. However, China does not show up on high scale in terms of scholarly impact per publication. This may call upon China to improve its research quality to gain more scholarly impact.
3. Among the selected institutes, Japanese research characteristics in terms of scholarly impact per publication is close to other selected non-Asian nations in Sustainable Development overall.
4. The combination of country level and institute level analyses shows that although India, Spain and Italy are among the top countries in research in Sustainable Development and its sub-areas, they do not have institutions ranked among the top tier due to the fact that their national research strengths are highly distributed among

institutions. This may call for these countries to make efforts to coordinate their national research activities in order to increase impact.

5. The analyses at institute level indicate that institutes strong in Sustainable Development may not be strong in all sub-areas and that institutes not strong in Sustainable Development overall may have significant niche strengths in select sub-areas. Such analyses can be useful in order to help government research agencies to understand how to more effectively knit together the various niche strengths in a country, to help institutes to find strategic partners that can complement their strengths, and to help institutes to make important resource allocation decisions.

In conclusion, this study helps to understand research landscape in important, but heterogeneous, area of Sustainable Development. In order to conduct bibliometric analysis related to Sustainable Development field and its sub-areas, the keyword collection approach appears to be very useful. This approach is flexible and can be used to conduct such analysis for any niche research area. In future, we plan to use more sophisticated indicators including size of institutes. Also, we plan to include the remaining sub-area of Sustainable Development as well.

**Acknowledgments** We are thankful to the domain experts who helped us to vet the keywords to define sub-areas of Sustainable Development.

## Appendix 1

See the Appendix Tables [5](#), [6](#), [7](#), [8](#), [9](#), [10](#), [11](#), [12](#), [13](#), [14](#), [15](#), [16](#), [17](#), [18](#), [19](#), [20](#), [21](#).

**Table 5** Sustainable Development taxonomies by The World Bank, UNDESA and OECD

Taxonomy	Category	Detail
The World Bank	<i>Agriculture and Rural Development</i>	Food Crisis, Agricultural Education and Training, Agricultural Extension, Agricultural Research, Agricultural Trade, Biodiversity, Commodity Risk Management (temporarily unavailable), Community Based Rural Development, Fisheries and Aquaculture, Forests and Forestry, Gender and Rural Development, Irrigation and Drainage: Water for Food, Land Policy and Administration, Land Resources Management, Livestock and Animal Resources, Natural Resource Management Institutions, Producer Organizations, Rural Finance, Rural Private Sector Development, Rural Water Supply and Sanitation, Water Resources Management.
	<i>Energy</i>	Electricity Access, Renewable Energy & Energy Efficiency, Clean Energy & Climate Change, Power Sector Reform.
	<i>Environment</i>	Forests and Forestry, Climate Change, Carbon Finance, Corporate Responsibility, Coastal & Marine Management, Biodiversity, Environmental Economics & Indicators, Environmental Health, Country Environmental Analysis.
	<i>Social Development</i>	Community Driven Development, Conflict prevention and Reconstruction, Indigenous Peoples, Involuntary Resettlement, Participation and Civic Engagement, Social Analysis, Social Capital, Social Policy.
	<i>Transport</i>	Air Transport, Ports & Waterborne Transport, Railways, Roads & Highways, Road Safety, Rural Transport, Trade Logistics & Facilitation, Transport Economics, Policy & Poverty, Transport & Social Responsibility, Urban Transport.
	<i>Urban Development</i>	Housing & Land, Municipal Finance, Urban Upgrading & Slum Prevention, Urban Solid Waste Management, Urban Environment & Climate Change, Local Economic Development, Urban Poverty, Cultural Heritage and Sustainable Tourism, Disaster Risk Management, Urban Health.
	<i>Water</i>	Water Supply & Sanitation, Irrigation & Drainage, Hydropower, Water Resources Management.
	<i>Global Information and Communication Technologies</i>	Information for Development Program (infoDev), Earth Observation for Development
	<i>Infrastructure</i>	Infrastructure Recovery and Assets Platform (INFRA), PPI Database, PPP in Infrastructure Resource Center for Contracts, Laws and Regulation (PPPIRC)
	<i>Oil, Gas, and Mining</i>	Oil, Gas, and Mining Portal, The Extractive Industries Transparency Initiative (EITI), The Global Gas Flaring Reduction Partnership (GGFR), Communities and Artisanal & Small-Scale Mining (CASM), Petroleum Governance Initiative, Extractive Industries and Gender, Extractive Industries Technical Advisory Facility

**Table 5** continued

Taxonomy	Category	Detail
UNDESA	<i>Social &amp; Economic</i>	Industry, Poverty, Sustainable Consumption & Production Patterns, Sustainable Tourism, Trade, Demographics, Health, Human Settlements
	<i>Natural Resource Management</i>	Agriculture, Desertification & Drought, Rural Development, Biodiversity, Forests, Land, Mountains, Oceans & Seas, Sanitation, Water/Freshwater, Atmosphere, Climate Change, Disaster Reduction & Management, Energy, Transport, Chemicals, Toxic Chemicals, Waste (Hazardous), Waste (Radioactive), Waste (Solid)
OECD	<i>Biodiversity, Water and Natural Resource Management</i>	N/A
	<i>Climate Change</i>	N/A
	<i>Consumption, Production and the Environment</i>	N/A
	<i>Environment and Development</i>	N/A
	<i>Environment and Sustainable Development: Economic Issues</i>	N/A
	<i>Environment in Emerging and Transition Economies</i>	N/A
	<i>Environmental Indicators and Outlooks</i>	N/A
	<i>Environmental Policies and Instruments</i>	N/A
	<i>Fisheries</i>	N/A
	<i>Green innovation</i>	N/A
	<i>Sustainable Agriculture</i>	N/A
	<i>Trade, Investment and Environment</i>	N/A
	<i>Transport and Environment</i>	N/A

**Table 6** Research strengths of top ten countries in terms of publication output in the sub-area Rural Development during 2000–2010

Country	(00–05)	(01–06)	(02–07)	(03–08)	(04–09)	(05–10)
Australia	355	423	509	614	694	812
Canada	327	393	448	530	597	660
China	122	161	215	284	380	467
France	146	186	213	242	283	302
Germany	184	190	206	245	281	336
India	332	357	403	462	503	591
South Africa	181	209	247	272	276	318
Spain	150	178	210	231	256	301
United Kingdom	711	775	870	950	993	1,085
United States	2,096	2,368	2,547	2,757	2,877	3,146

**Table 7** Research strengths of top ten countries in terms of publication output in the sub-area Urban Development during 2000–2010

Country	(00–05)	(01–06)	(02–07)	(03–08)	(04–09)	(05–10)
Australia	454	527	613	718	865	1015
Canada	575	647	756	843	905	1045
China	613	886	1,249	1,722	2,452	3,323
France	487	527	574	612	651	732
Germany	466	484	540	607	656	725
Italy	339	387	430	485	516	575
Japan	334	387	417	472	510	545
Netherlands	442	492	545	604	662	742
United Kingdom	1,593	1,686	1,818	2,008	2,078	2,278
United States	3,264	3,671	4,098	4,538	4,880	5,523

**Table 8** Research strengths of top ten countries in terms of publication output in the sub-area Transport during 2000–2010

Country	(00–05)	(01–06)	(02–07)	(03–08)	(04–09)	(05–10)
Australia	746	855	955	1,086	1,174	1,379
Canada	1,149	1,303	1,471	1,608	1,748	1,939
China	1,546	2,170	2,843	3,655	4,640	5,810
France	1,223	1,329	1,420	1,551	1,633	1,824
Germany	1,539	1,659	1,807	2,012	2,135	2,402
Italy	648	714	769	828	880	962
Japan	1,527	1,644	1,741	1,844	1,922	2,090
South Korea	675	796	907	1,015	1,119	1,260
United Kingdom	1,816	1,923	2,119	2,327	2,493	2,704
United States	8,376	8,726	9,155	9,561	10,019	11,015



**Table 9** Research strengths of top ten countries in terms of publication output in the sub-area Agriculture during 2000–2010

Country	(00–05)	(01–06)	(02–07)	(03–08)	(04–09)	(05–10)
Australia	488	513	561	591	621	683
Brazil	160	195	231	277	357	482
Canada	343	395	415	472	491	490
China	310	407	506	615	747	988
France	205	239	284	335	393	493
Germany	474	503	530	576	618	703
India	337	374	409	450	493	560
Netherlands	285	301	336	359	366	412
United Kingdom	606	611	652	665	670	714
United States	1,947	1,995	2,137	2,251	2,264	2,487

**Table 10** Research strengths of top ten countries in terms of publication output in the sub-area Fisheries during 2000–2010

Country	(00–05)	(01–06)	(02–07)	(03–08)	(04–09)	(05–10)
Australia	659	727	859	962	1,041	1,158
Canada	714	774	883	984	1,039	1,138
China	164	258	349	473	614	837
France	398	433	477	520	605	698
Italy	284	324	370	417	449	506
Japan	336	390	438	476	519	532
Norway	266	318	395	456	523	579
Spain	342	410	467	562	636	747
United Kingdom	726	789	886	988	1,037	1,149
United States	2,383	2,624	2,923	3,189	3,295	3,527

**Table 11** Research strengths of top ten countries in terms of publication output in the sub-area Sustainable Consumption and Production during 2000–2010

Country	(00–05)	(01–06)	(02–07)	(03–08)	(04–09)	(05–10)
Australia	213	245	332	382	424	478
Canada	318	380	459	532	607	701
China	245	339	457	639	859	1,087
Germany	392	419	469	530	559	621
India	239	277	304	363	386	428
Japan	283	339	414	481	487	526
Netherlands	288	312	337	392	400	412
Sweden	317	341	369	388	397	400
United Kingdom	665	740	836	949	987	1,064
United States	1,528	1,701	1,960	2,148	2,344	2,570

**Table 12** Research strengths of top ten countries in terms of publication output in the sub-area Water during 2000–2010

Country	(00–05)	(01–06)	(02–07)	(03–08)	(04–09)	(05–10)
Australia	2,812	3,134	3,492	3,928	4,341	4,877
Canada	3,111	3,347	3,738	4,163	4,408	4,748
China	4,698	6,466	8,210	10,513	13,268	16,697
France	2,817	3,002	3,214	3,493	3,665	4,082
Germany	4,379	4,525	4,861	5,044	5,378	5,809
India	2,602	2,903	3,274	3,700	3,945	4,503
Japan	2,747	3,024	3,319	3,612	3,814	3,947
Spain	2,305	2,616	2,991	3,410	3,875	4,414
United Kingdom	4,450	4,671	5,085	5,250	5,447	5,762
United States	16,620	17,650	18,893	19,888	21,108	23,017

**Table 13** Research strengths of top ten countries in terms of publication output in the sub-area Waste during 2000–2010

Country	(00–05)	(01–06)	(02–07)	(03–08)	(04–09)	(05–10)
Canada	970	1,050	1,181	1,326	1,484	1,668
China	1,921	2,706	3,530	4,577	5,822	7,216
France	856	951	1,076	1,222	1,372	1,536
Germany	1,292	1,320	1,368	1,430	1,443	1,503
India	1,162	1,324	1,487	1,712	1,875	2,200
Italy	688	730	804	919	1,070	1,131
Japan	1,715	1,970	2,158	2,283	2,339	2,440
Spain	890	1,041	1,165	1,283	1,393	1,527
United Kingdom	1,542	1,651	1,722	1,834	1,897	1,990
United States	4,599	4,828	5,269	5,634	6,131	7,031

**Table 14** Research strengths of top 15 institutions in terms of publication output in the sub-area Rural Development during 2000–2010

Institute	Country	Pubs	Cites	CPP
The University of North Carolina at Chapel Hill	United States	85	525	6.18
UC Berkeley	United States	81	485	5.99
Cornell University	United States	92	428	4.65
Wageningen University	Netherlands	93	404	4.34
University of Wisconsin Madison	United States	64	379	5.92
UC Davis	United States	78	314	4.03
Iowa State University	United States	86	311	3.62
Ohio State University	United States	73	304	4.16
Michigan State University	United States	66	256	3.88
The University of British Columbia	Canada	80	228	2.85
Pennsylvania State University	United States	70	217	3.1

**Table 14** continued

Institute	Country	Pubs	Cites	CPP
The University of North Carolina at Chapel Hill	United States	85	525	6.18
UC Berkeley	United States	81	485	5.99
Cornell University	United States	92	428	4.65
Wageningen University	Netherlands	93	404	4.34

**Table 15** Research strengths of top 15 institutions from all over the world in terms of publication output in the sub-area Urban Development during 2005–2010

Institute	Country	Pubs	Cites	CPP
Arizona State University	United States	204	1,191	5.84
The University of North Carolina at Chapel Hill	United States	127	1,139	8.97
University of Maryland	United States	122	1,105	9.06
University of Washington Seattle	United States	125	1,056	8.45
The University of British Columbia	Canada	125	991	7.93
UC Berkeley	United States	159	793	4.99
The University of Hong Kong	Hong Kong, SAR	130	617	4.75
University of Toronto	Canada	115	572	4.97
University College London	United Kingdom	141	566	4.01
Chinese Academy of Sciences	China	254	554	2.18
Institute of Geographical Sciences and Natural Resources Research	China	154	479	3.11
Delft University of Technology	Netherlands	183	358	1.96
Peking University	China	170	297	1.75
Nanjing University	China	195	283	1.45
Graduate University of Chinese Academy of Sciences	China	179	222	1.24

**Table 16** Research strengths of top 15 institutions from all over the world in terms of publication output in the sub-area Transport during 2005–2010

Institute	Country	Pubs	Cites	CPP
UC Berkeley	United States	256	2,601	10.16
University of Wisconsin Madison	United States	222	2,479	11.17
UC Davis	United States	196	1,861	9.49
University of Washington Seattle	United States	154	1,776	11.53
University Michigan Ann Arbor	United States	210	1,584	7.54
CNRS Centre National de la Recherche Scientifique	France	178	1,553	8.72
Ohio State University	United States	188	1,294	6.88
Zhejiang University	China	232	1,229	5.3
Argonne National Laboratory	United States	170	1,148	6.75
Tsinghua University	China	304	1,013	3.33
Chinese Academy of Sciences	China	256	903	3.53

**Table 16** continued

Institute	Country	Pubs	Cites	CPP
University of Tokyo	Japan	173	614	3.55
Shanghai Jiaotong University	China	240	590	2.46
IEEE	United States	210	575	2.74
Harbin Institute of Technology	China	307	516	1.68

**Table 17** Research strengths of top 15 institutions from all over the world in terms of publication output in the sub-area Agriculture during 2005–2010

Institute	Country	Pubs	Cites	CPP
USDA Agricultural Research Service, Washington DC	United States	271	1,320	4.87
Wageningen University	Netherlands	198	1,318	6.66
UC Davis	United States	116	814	7.02
Swedish University of Agricultural Sciences	Sweden	116	793	6.84
Michigan State University	United States	102	718	7.04
Iowa State University	United States	92	568	6.17
Chinese Academy of Sciences	China	144	544	3.78
Research Centre Flakkebjerg	Denmark	62	517	8.34
Cornell University	United States	69	477	6.91
Agriculture and Agri-Food Canada	Canada	86	460	5.35
Empresa Brasileira de Pesquisa Agropecuária—Embrapa	Brazil	100	445	4.45
Ohio State University	United States	64	405	6.33
United States Department of Agriculture	United States	79	375	4.75
University of Florida	United States	126	369	2.93
China Agricultural University	China	130	350	2.69

**Table 18** Research strengths of top 15 institutions from all over the world in terms of publication output in the sub-area Fisheries during 2005–2010

Institute	Country	Pubs	Cites	CPP
James Cook University	Australia	195	2,054	10.53
The University of British Columbia	Canada	224	1,690	7.54
University of Washington Seattle	United States	199	1,583	7.95
NOAA Fisheries Service	United States	138	1,378	9.99
Centre for the Environment Fisheries and Aquaculture Science	United Kingdom	132	1,317	9.98
Dalhousie University	Canada	135	1,227	9.09
CSIRO Marine and Atmospheric Research	Australia	146	934	6.4
UC Davis	United States	115	919	7.99
NOAA National Marine Fisheries Service Northwest Regional Office	United States	147	833	5.67
University of Tasmania	Australia	139	769	5.53
University of Cape Town	South Africa	115	734	6.38
Oregon State University	United States	108	678	6.28
Institute of Marine Research	Norway	115	660	5.74

**Table 18** continued

Institute	Country	Pubs	Cites	CPP
Fisheries and Oceans Canada	Canada	117	587	5.02
University of Stirling	United Kingdom	103	546	5.3

**Table 19** Research strengths of top 15 institutions from all over the world in terms of publication output in the sub-area Sustainable Production and Consumption during 2005–2010

Institute	Country	Pubs	Cites	CPP
United States Environmental Protection Agency	United States	121	641	5.3
The Technical University of Denmark	Denmark	69	487	7.06
The Royal Institute of Technology (KTH)	Sweden	49	448	9.14
Yale University	United States	43	434	10.09
University of Regina	Canada	63	431	6.84
ETH Zurich	Switzerland	72	429	5.96
Norwegian University of Science and Technology	Norway	62	402	6.48
Lunds Universitet	Sweden	56	399	7.13
Leiden University	Netherlands	46	393	8.54
Tsinghua University	China	90	377	4.19
Delft University of Technology	Netherlands	64	323	5.05
University of Surrey	United Kingdom	47	300	6.38
Chalmers University of Technology	Sweden	49	289	5.9
University of Tokyo	Japan	72	267	3.71
North Carolina State University	United States	65	204	3.14

**Table 20** Research strengths of top 15 institutions from all over the world in terms of publication output in the sub-area Water during 2005–2010

Institute	Country	Pubs	Cites	CPP
United States Geological Survey	United States	871	6,537	7.51
Chinese Academy of Sciences	China	1,273	4,470	3.51
USDA Agricultural Research Service, Washington DC	United States	769	4,381	5.7
UC Davis	United States	660	4,230	6.41
University of Arizona	United States	580	4,166	7.18
University of Tokyo	Japan	478	3,675	7.69
University of Florida	United States	691	3,311	4.79
Wageningen University	Netherlands	522	3,306	6.33
Universiteit Gent	Belgium	454	3,086	6.8
Texas A and M University	United States	522	2,824	5.41
United States Environmental Protection Agency	United States	497	2,550	5.13
Universidade de Sao Paulo	Brazil	511	1,759	3.44
Tsinghua University	China	715	1,639	2.29
Graduate University of Chinese Academy of Sciences	China	655	1,492	2.28
Harbin Institute of Technology	China	739	1,165	1.58

**Table 21** Research strengths of top 15 institutions from all over the world in terms of publication output in the sub-area Waste during 2005–2010

Institute	Country	Pubs	Cites	CPP
The Technical University of Denmark	Denmark	211	1,311	6.21
Tsinghua University	China	488	1,101	2.26
United States Environmental Protection Agency	United States	208	959	4.61
National Institute of Advanced Industrial Science and Technology	Japan	158	903	5.72
Imperial College London	United Kingdom	200	901	4.51
Zhejiang University	China	440	815	1.85
University of Florida	United States	145	778	5.37
Southeast University	China	368	704	1.91
Tongji University	China	334	668	2.00
Chinese Academy of Sciences	China	232	644	2.78
University of Tokyo	Japan	186	570	3.06
Kyoto University	Japan	174	498	2.86
Huazhong University of Science and Technology	China	238	470	1.97
Harbin Institute of Technology	China	229	397	1.73
China University of Mining Technology	China	202	265	1.31

## Appendix 2

List of domain experts who helped to vet the keywords to define sub-areas of Sustainable Development

Prof. Tony Dalton (RMIT)

Prof. John Fien (RMIT)

Prof. Felicity Roddick (RMIT)

Dr. Sahra Bekessey (RMIT)

Dr. V V N Kishore (TERI University)

Dr. Rajiv Seth (TERI University)

Dr. Zhou Ping (ISTIC)

Dr. Junguo Liu (Beijing Forestry University)

Dr. Chen Guoqian (College of Engineering, Peking University)

Dr. Cheng Ming (Electrical Engineering School, Southeast University)

Dr. Liu Chunhua (Hong Kong University)

Dr. Li Xiaodong (Macau University of Science and Technology)

Dr. Yu Xianjun (Beijing University of Aeronautics & Astronautics)

Dr. Li YongFang (Key Laboratory of Organic Solids, Institute of Chemistry, Chinese Academy of Sciences)

Dr. Dai SongYuan (Key Laboratory of Novel Thin-Film Solar Cells, Institute of Plasma Physics, Chinese Academy of Sciences)

Dr. Wu JiHuai (Institute of Materials Physical Chemistry, Key Laboratory for Functional Materials of Fujian Higher Education)

Dr. Zhang JingBo (Beijing National Laboratory for Molecular Sciences, Key Laboratory of Photochemistry, Institute of Chemistry, Chinese Academy of Sciences)

Dr. Weng Jian (Key Laboratory of Novel Thin Film Solar Cells, Institute of Plasma Physics, Chinese Academy of Sciences)

Prof. Tanaka Noriyuki (Center for Sustainability Science, Hokkaido University)

Prof. Nagano Katsunori (Engineering Division of Human Environmental System Rural Development, Hokkaido University)

Prof. Osanami Fumio (Agriculture Division of Bio-resources and Product Science Research Group of Agricultural Economics, Hokkaido University)

Prof. Miyashita Kazushi (Field Science Center for Northern Biosphere Aquatic Research Station, Hokkaido University)

Prof. Yoshida Toshiya (Field Science Center for Northern Biosphere Forest Research Station Northern Forestry Research and Development Office, Hokkaido University)

Prof. Matsuto Toshihiko (Engineering Division of Built Environment, Hokkaido University)

Dr. Uchida Kenetsu (Assistant Professor at Engineering Division of Engineering and Policy for Cold Regional Environment, Hokkaido University)

### Appendix 3

#### Agriculture

**Keywords:** “agricultural sustainability”, “agrobiodiversity”, “agroecology”, “alternative agriculture”, “climate friendly agriculture”, “cover crops”, “crop rotation”, “ecological agriculture”, “farming systems”, “grain for green”, “industrial agriculture”, “organic agriculture”, “organic farming”, “pastoralism”, “pastoralists”, “precision agriculture”, “precision farming”, “rainwater harvesting”, “shifting cultivation”, “slash-and-burn agriculture”, “sustainable agriculture”, “swidden agriculture”, “urban agriculture”, “desertification AND “agriculture”, “rainfed cultivation”, “subsistence agriculture”, “environmental degradation”, “integrated management practices”, “conventional farming system”

**Keywords limited to source titles:** “indigenous knowledge”, “sustainability”, “weed control”, “nitrate leaching”, “desertification”, “sustainable development”

**Source Titles:** Agriculture, Ecosystems and Environment, Journal of Agricultural and Food Chemistry, Journal of Food, Agriculture and Environment, Australian Journal of Experimental Agriculture, Transactions of the American Society of Agricultural Engineers, Biological Agriculture and Horticulture, Agronomy for Sustainable Development, International Journal of Sustainable Development and World Ecology, Nongye Gongcheng Xuebao/ Transactions of the Chinese Society of Agricultural Engineering

#### Biodiversity

**Keywords:** biodiversity conservation”, “species-area relationship”, “threatened species”, “forest management”, “habitat loss”, “conservation planning”, “invasive species”, “nature conservation”, “indicator species”, “species richness”, “plant diversity”, “biodiversity”, “protected areas”, “marine biodiversity”, “species diversity”, “exotic species”, “habitat fragmentation”, “endangered species”, “marine protected areas”.

**Keywords limited to source titles:** “ecosystem services”, “ecosystem function”, “ecosystem functioning”, “endemism”, “macroecology”, “landscape ecology”, “ethnobotany”, “deforestation”, “ecosystem management”, “neotropics”, “tropical forest”, “phylogeography”, “vascular plants”, “macroinvertebrates”, “conservation”, “madagascar”, “reserve selection”

**Source titles:** Biological Conservation, Conservation Biology, Biodiversity and Conservation, Conservation Genetics, Journal of Soil and Water Conservation, Aquatic Conservation: Marine and Freshwater Ecosystems, Animal Conservation, Environmental Conservation, Journal of Insect Conservation, Diversity and Distributions, Bird Conservation International

Climate Change:

**Keywords:** “climatic changes”, “climate warming”, “climate change”, “kyoto protocol”, “intergovernmental panel on climate change (ipcc)”, “climate policy”, “paleoclimate”, “global climate change”, “climate variability”, (“carbon sequestration” AND “climate”), “global change”.

**Keywords limited to source titles:** “global warming”, “global change”, “phenology”, “carbon sequestration”, “holocene”, “greenhousegases”, “palynology”, “greenhouse effect”, “permafrost”, “north atlantic oscillation”, “extreme events”, “drought”, “land use change”, “sea-level rise”, “radiative forcing”, “human impact”, “greenhouse gas emissions”, “deforestation”, “stable isotopes”, “streamflow”, “sea ice”, “enso”, “floods”

**Source titles:** Journal of Climate, Journal of Geophysical Research D: Atmospheres, International Journal of Climatology, Climatic Change, Geophysical Research Letters, Journal of Hydrology, IAHS-AISH Publication, Global and Planetary Change, Climate Research, Climate Dynamics, Hydrological Processes, Natural Hazards, Theoretical and Applied Climatology, Hydrological Sciences Journal, Stochastic Environmental Research and Risk Assessment, Journal of Hydrologic Engineering, Mitigation and Adaptation Strategies for Global Change, Advances in Geosciences, Water Resources Research, Hydrology and Earth System Sciences, Natural Hazards and Earth System Science, Hydrology and Earth System Sciences Discussions, Global Change Biology, Geographia Polonica.

Renewable Energy:

**Keywords:** “renewable energy”, “renewable energy systems”, “renewable energy sources”, “renewable energy technologies”, “renewable energies”, “alternative energy”, “sustainable energy”, “solar energy”, “water energy”, “wind power generation”, “wind energy”, “biomass energy”, “geothermal energy”, “bioenergy”, “photovoltaic”, “dye-sensitized solar cells”, “dye-sensitized solar cell”, “photovoltaic cell”, “photovoltaic cells”, “organic solar cell”, “organic solar cells”, “microbial fuel cell”, “photovoltaic power systems”, “organic photovoltaics”, “organic photovoltaic”, “wind energy generation”, “wind energy potential”, “wind generator systems”, “wind energy conversion system (wecs)”, “wind energy conversion system”, “wind turbines”, “solar cell”, “solar cells”, “solar collector”, “wind park”, “offshore wind energy”, “wind power plant”, “wind farm”, “wind generator”, “biogas”, “wave energy”, “biofuels”, “hydropower”, “biofuel”, “renewable resources”, “wind farm”, “wind power”, “photovoltaics”, “wind turbine”, “biodiesel”, “energy crops”, “renewables”, “wind power density”, “photovoltaic effect” AND (“sustainable development” OR (“sustainability” OR “sustainable”)), “wind characteristics” AND (“sustainable development” OR (“sustainability” OR “sustainable”)), “geothermal energy”, “geothermal power”, “geothermal power generation”, “thermal energy storage”, “downhole heat exchanger”, “geothermal heating”, “geothermal heat pumps”, “geothermal heat pump”, “ground-coupled heat pump”, “enhanced geothermal system”, “geothermal power plant”, “latent heat thermal



energy storage”, “enhanced geothermal systems”, (“space heating” OR “space cooling”) AND (“geothermal” OR “geothermics”), “ground source heat pump” “geothermal resources” “underground thermal energy storage” “phase change material (PCM)

## Fisheries

**Keywords:** “sustainable fisheries”, “marine protected areas”, “marine reserves”, “ccamlr”, “bycatch”, “artisanal fisheries”, “overfishing”, “aquaculture”, “fish biomass”, “fish farming”, “fisheries management”, “fishery management”, “shrimp aquaculture”, “integrated aquaculture”, “mariculture”, “marine reserve”, (“fisheries” AND (“sustainable development” OR “sustainability”)), (“fishery” AND (“sustainable development” OR “sustainability”)), (“fisheries management” AND (“sustainable development” OR “sustainability”)), (“fishery management” AND (“sustainable development” OR “sustainability”)), (“haddock” AND (“sustainable development” OR “sustainability”)), (“seabirds” AND “fish” AND (“sustainable development” OR “sustainability”)), (“atlantic salmon” AND (“sustainable development” OR “sustainability”)), (“longline” AND (“sustainable development” OR “sustainability”)), (“trawling” AND (“sustainable development” OR “sustainability”)), (“cod” AND “fish” AND “farm” AND (“sustainable development” OR “sustainability”)), (“salmon” AND “farm” AND (“sustainable development” OR “sustainability”)), (“gadus morhua” AND “farm” AND (“sustainable development” OR “sustainability”)), (“fishing” AND (“sustainable development” OR “sustainability”)), (“fish stocking” AND (“sustainable development” OR “sustainability”)), (“salmo salar” AND “farm” AND (“sustainable development” OR “sustainability”)), (“herring” AND “farm” AND (“sustainable development” OR “sustainability”)), (“shrimp” AND “farm” AND (“sustainable development” OR “sustainability”)), (“barramundi” AND “farm” AND (“sustainable development” OR “sustainability”)), (“rainbow trout” AND “farm” AND (“sustainable development” OR “sustainability”)), (“farmed aquatic animal” AND (“sustainable development” OR “sustainability”)), (“fish” AND (“sustainable development” OR “sustainability”))

**Keywords limited to source titles:** “tilapia”, “penaeus monodon”, “rainbow trout”, “oreochromis niloticus”, “longline”, “atlantic salmon”, “salmo salar”, “salmon”

**Source titles:** Aquaculture Economics and Management, Aquatic Conservation: Marine and Freshwater Ecosystems, Aquatic Ecosystem Health and Management, Biological Conservation, CCAMLR Science, Conservation Genetics, Ecology, Environment and Conservation, Fisheries Management and Ecology, North American Journal of Fisheries Management

## Forestry:

**Keywords:** “sustainable forestry”, “forest sustainability”, “sustainable forest management” “community forestry”, “agroforestry”, “urban forestry”, “natural regeneration”, “silviculture”, “coarse woody debris”, “boreal forest”, “forest inventory”, “afforestation”, “reforestation”, “forest structure”, “deforestation”, “wildfire”, “forest fire”, “leaf area index”, “tropical forest”, “stand structure”, “forest health”, “forest policy”, “forest fragmentation”, “forest fires”, “forest management”, “forest dynamics”, “prescribed fire”, “secondary forest”, “tropical deforestation”, “leaf area index (lai)”, “tropical forests”, “tropical rain forest”, (“forest soil” AND “forestry”), (“thinning” AND “forestry”), (“forestry” AND (“sustainable development” OR “sustainability”))

**Keywords limited to source titles:** “lai”, “carbon sequestration”, “pinus ponderosa”, “ponderosa pine”, “picea abies”, “pinus sylvestris”

**Source titles:** Agroforestry, Boreal forest, Coarse woody debris, Community forestry, Deforestation, Forest fire, Forest health, Forest inventory, Forest policy, Forest structure, Forest sustainability, Leaf area index, Natural regeneration, Reforestation, Silviculture, Stand structure, Sustainable forest management, Sustainable forestry, Tropical foresturban forestry, wildfire

Rural Development:

**Keywords:** “rural sociology”, “rural geography”, “rural communities”, “agrarian economics”, “rural population”, “rural communities”, “rural community”, “local knowledge”, “rural development”, “rural geography”, “rural tourism”, “rural sociology”, “rural health”, “environmental sociology”, (“deep structure” AND “sociology”), (“farming” AND “sociology”), “logger training”, “natural resource sociology”, “rural ecology”, “rural economics”, “rural sociology discrete choice models”, (“folk classification” AND “sociology”), (“genetic counselling” AND “sociology”), (“consanguinity” AND (“sustainable development” OR “sustainability”)), “area de conservacion Guanacaste”, “mountain farms”, “agricultural economics”.

**Keywords limited to source titles:** “family farms”, “farm succession”, “spatial econometrics”, “social capital”, “non-timber forest products”, “rurality”, “telehealth”, “rural areas”, “technology adoption”, “organic farming”

**Source titles:** Agricultural Economics, Agriculture and Human Values, Agronomy for Sustainable Development, American Journal of Agricultural Economics, American Journal of Alternative Agriculture, Australian Journal of Experimental Agriculture, Community Development Journal, Developing Economies, Development Southern Africa, Ecological Economics, Energy for Sustainable Development, Entrepreneurship and Regional Development, Environment, Development and Sustainability, Forest Policy and Economics, Handbook of Agricultural Economics, Indian Journal of Agricultural Economics, International Journal of Sustainable Development and World Ecology, Journal of Agrarian Change, Journal of Agricultural and Resource Economics, Journal of Agricultural Economics, Journal of Agriculture and Rural Development in the Tropics and Subtropics, Journal of Development Economics, Journal of Family and Economic Issues, Journal of International Development, Journal of Rural Cooperation, Journal of Rural Development, Journal of Rural Health, Journal of R Studies, Land Degradation and Development, Livestock Research for Rural Development, Mountain Research and Development, Research in Rural Sociology and Development, Review of Development Economics, Review of Economics of the Household, Rural and remote health, Rural Sociology, Sociologia Ruralis, Tijdschrift voor Economische en Sociale Geografie, World Development

Sustainable production and consumption

**Keywords:** “sustainable production”, “sustainable consumption”, “cleaner production”, “environmental product policy”, “sustainable procurement”, “sustainable energy use”, “waste management”, “industrial ecology”, “green marketing”, “life-cycle thinking”, “industrial symbiosis”, “green innovation”, “green process innovation”, “green product innovation”, “pollution prevention”, “life cycle assessment”, “eco-efficiency”, “waste minimization”, “sustainable production and consumption”, “sustainable consumption and production”, “environmental management accounting”, “integrated

product policy”, “industrial sustainability”, “green consumerism”, “sustainable chemistry”, “eco-supply chain”, “greening of industry”, “green core competence”, “product stewardship”, “steady-state economy”, “ecospace”, “ecological footprint”, “natural resource accounting”, “life cycle costing”, “whole-of-life- costing”, “sustainable lifestyle”,  
**Keywords limited to source titles:** “rebound effect”, “fair trade”, “recycling”, “product service system”, “input–output analysis”, “basic human needs”

**Source titles:** Ecological Economics, Journal of Industrial Ecology, Energy Policy, International Journal of Life Cycle Assessment, Environmental Science and Technology, Ecological Modelling, Journal of Environmental Management, Energy and Environment, WIT Transactions on Ecology and the Environment

Transport:

**Keywords:** “sustainable urban mobility”, “sustainable cities”, “sustainable mobility”, “sustainable urban transport”, “sustainable transport policy”, “sustainable transport and mobility”, “sustainable transport performance indicators”, “environmental impacts of urban transport”, “sustainable transportation”, “green car”, “green mobility”, “liquid nitrogen powered engine”, “electric vehicles (evs)”, “electric vehicles”, “electric vehicle”, “electric vehicle (ev)”, (“eco-design” OR “ecodesign” OR “design for environment” OR “environment friendly”) AND “transportation”, “sustainable transport indicators”, “car sharing”, “slowly increasing steer”, “marginal willingness to pay for car efficiency”, “intelligent car”, “safety belt”, “vehicle security”, “safety vehicular communication”, “vehicle safety communications”, “child safety seat”, “sustainable transport”, “transport sustainability”, “transport emission reduction”, “green vehicles”, “green transport”, “cycling”, “transit oriented development”, “fuel efficient AND vehicle”, “fuel efficient AND transport”, “hybrid electric vehicles”, “hybrid vehicles”, “fuel cell electric vehicle (fcev)”, “fuel cell electric vehicle”, “hybrid and alternative drive vehicles”, “road vehicle electric propulsion”, “regenerative braking”, “hybrid vehicle”, “hybrid electric vehicle (hev)”, “plug-in hybrid electric vehicle”, “hybrid electric vehicles (hevs)”, “hybrid electric vehicle”, “eco-driving”, “car clubs”, “bicycling”, “light rail transit”, “seat belt”, “pedestrian safety”, “traffic safety”, “motor vehicle safety”, “vehicle safety”, “motor vehicle crash”, “vehicle crash test”.

**Keywords ANDed with (“sustainability” OR “sustainable development”):** “public transport policy”, “inland shipping”, “intermodal transport”, “inland waterway navigation”, “public transport”, “transport management”, “rail freight”, “traffic congestion”, “freight station”, “bus transport priority measures”, “urban mobility”, “urban transport strategy formulation”, “urban transport policy”, “urban traffic control”, “urban transport”, “maritime transport”, “maritime safety”, “port efficiency”, “maritime traffic”, “intermodality”, “container port”, “port development”, “container related costs and expenses”, “container security initiative”, “croatian transport system”, “customs trade partnership against terrorism”, “degressive tariffs”, “urban freight logistic”, “rail freight vehicles”, “rail freight cars”, “long intermodal freight train”, “internet freight exchanges”, “innovations in freight transport”, “fleet management systems”, “feeder transport”, “freight transport”, “road freight transport”, “urban freight transport”, “intermodal freight transport”, “railway freight transport”, “freight transportation”, “multimodal transport”, “passenger transport”, “transport planning”, “travel demand management”, “road pricing”, “non-motorized transport”, “transport economics”, “inter-vehicle networks”, “aeronautics”, “aircraft”, “air transport”, “airspace”, “air traffic control”, “civil aviation”, “air traffic management”, “aircraft communication”, “rail transport”, “high

pressure common rail system”, “wheel-rail system”, “common rail system”, “railway transport”, “urban rail”, “rail system”, “intermodal terminal”, “rail corrugation”, “high pressure common rail”, “railway engineering”, “rail transportation”, “railway transportation”, “railway systems”, “efreight”, “electronic freight”, “multinomial logit model”, “nested logit model”, “modal shift”, “crashworthiness”, “head and neck injury potential”, “transport policy”, “urban transportation”, “urban public transport”, “urban traffic”, “sustainable urban transport”, “traffic planning”, “traffic management”, “road transport”, “rural transport”, “community transport”, “freight modal shift”, “park-and-ride”, “integrated transport policy”, “demand responsive transport”, “local transport planning”, “public urban transport”, “road safety”

## Urban Development

**Keywords:** “urban development”, “urban form”, “urban transport”, “urban transportation”, “urban planning”, “urban environment”, “urban climate”, “urban policy”, “urban regeneration”, “urban management”, “urban sprawl”, “urban growth”, “urban forestry”, “urbanisation”, “suburban development”, “suburban form”, “suburban transport”, “suburban transportation”, “suburban planning”, “suburban environment”, “suburban climate”, “suburban policy”, “suburban regeneration”, “suburban management”, “suburban sprawl”, “suburban growth”, “suburban forestry”, “suburbanisation”, “suburban ecology”, “suburban design”, “suburban renewal”, “suburban heat island”, “suburbanization”, “suburban morphology”, “suburban governance”, “suburban expansion”, “new suburbanism”, “suburban housing”, “suburban infrastructure”, “suburban strategy”, “suburban services”, “suburban footprint”, “suburban finance”, “suburban containment”, “suburban utilities”, “urban ecology”, “urban design”, “urban renewal”, “urban heat island”, “built environment”, “urbanization”, “urban morphology”, “urban governance”, “smart growth”, “regional planning”, “city planning”, “transit oriented development”, “urban expansion”, “new urbanism”, “urban housing”, “urban infrastructure”, “urban strategy”, “urban services”, “urban footprint”, “urban finance”, “urban containment”, “urban utilities”, “metropolitan planning”.

**Keywords limited to source titles:** “spatial planning”, “land use change”, “urban areas”, “housing”

**Source titles:** Built Environment, Town Planning Review, Planning Theory and Practice, International Planning Studies, Planning Practice and Research, WIT Transactions on Ecology and the Environment, Landscape and Urban Planning, Environment and Planning A, Land Use Policy, Environment and Planning C: Government and Policy, Landschap, Environment and Planning B: Planning and Design, Journal of Environmental Planning and Management, Urban Studies, Landscape Research, Habitat International, European Environment, Journal of Environmental Management, Journal of Housing and the Built Environment, Environmental Impact Assessment Review, Journal of Transport Geography, International Journal of Urban and Regional Research, Journal of Planning and Environment Law, Cities, Environmental Modelling and Software, Landscape Ecology.

## Waste

**Keywords:** “municipal solid waste”, “municipal solid waste (msw)”, “waste disposal”, “landfills”, “waste recycling”, “waste plastics”, “nuclear waste”, “fly ash”, “industrial waste”, “organic waste”, “hazardous waste”, “food waste”, “e-waste”, “waste materials”, “waste minimization”, “incineration”, “radioactive waste”, “landfill”, “solid waste”

management”, “waste activated sludge”, “solid wastes”, “waste utilization”, “solid waste”, “radioactive waste disposal”, “pyrolysis”, “composting”, “biogasification”, “energy from waste (EfW)”, “waste collection”, “gasification”, “biowaste”, “leachate treatment”, “packaging waste”, “biofuel production”, “source separation”, “source reduction”, “waste valorization”, “household waste”, “waste characterization”, “leaching test.

**Keywords limited to source titles:** “leachate”, “composting”, “recycling”

**Source titles:** Journal of Hazardous Materials, Waste Age, Journal of Environmental Science and Health - Part B Pesticides, Food Contaminants, and Agricultural Wastes, Journal of Environmental Science and Health - Part A Toxic/Hazardous Substances and Environmental Engineering, Journal of the Air and Waste Management Association

## Water

**Keywords:** “underground dams”, “water and sanitation”, “storage aquifers”, “shared water”, “floods monitoring”, “optimal water use”, “water productivity”, “water grabbing”, “water productivity”, “water stressed countries”, “water reuse”, “water inventory”, “water resources depletion”, “water pollution”, “water management”, “water resources management”, “water supply”, “water scarcity”, “water quality”, “water reuse”, “integrated water resources management”, “water use efficiency”, “watershed management”, “water shortage”, “soil and water conservation”, “sanitation and water conservation”, “water productivity”, (“groundwater” AND (“sustainability” or “sustainable development”)), “water policy”, “water pricing”, “water balance”, “water use”, “water conservation”, “water framework directive”, “rural water supply”, “water demand”, “water resources development”, “river basin management”, “groundwater quality”, “virtual water”, “urban water”, “water recycling”, (“water resources” AND (“sustainability” or “sustainable development”)), “water security”, “groundwater management”, “water resource management”, “groundwater recharge”, “submarine groundwater discharge”, “seawater intrusion”, “groundwater flow”, “groundwater contamination”, “water stress”, “surface water”, “eutrophication”, “rainwater harvesting”, “drought stress”, “drought”, “drought tolerance”, “desertification”, “drought resistance”, “water deficit”, “palmer drought severity index”, “drought avoidance”, “flood risk”, “flooding tolerance”, “flood control”, “flood defence”, “flood damage”, “river restoration”, “flood management”, “water logging”, “flood forecasting”, “flood simulation modelling”, “infiltration based storm water management”, “floodplain geomorphology”, “urban floods”, “flood hazard management”, “flood warning”, “floodplain restoration”, “integrated watershed modelling”, “integrated watershed management”, “water quality index”, “water footprint”, “grey water”, “green water footprint”, “blue water footprint”, “grey water footprint”, “potable water”, “wastewater management”, “waste water treatment”, “wastewater treatment plants”, “wastewater treatment plant”, “water reuse”, “water treatment”, “wastewater reuse”, “municipal wastewater”, “domestic wastewater”, “stormwater management”, “textile wastewater”, “drinking water treatment”, “sewage sludge”, “water recycling”, “wastewater treatment”, (“estrogens” or “estrogen” or “estrogenic”) AND (“water” or “wastewater” or “river”)), (“sulfonamides” AND (“water” or “river”) AND (“pollution” or “pollutant” or “pollutants” or “contaminant” or “contaminants” or “contamination”)), (“tributylphosphate” or “octylphenol” or “nonylphenol triazines” or “organophosphorus” or “acetanilides”) AND (“water” or “river”) AND (“pollution” or “pollutant” or “pollutants” or “contaminant” or “contaminants” or “contamination”)), (“pesticide” AND

(“river” or “water”)), (“polycyclic aromatic hydrocarbons” AND (“water” or “river”)), (“brominated flame retardants”, or “pentabromoethylbenzene” or “hexabromobenzene” or “decabromodiphenylethane”) AND (“river” or “water”)), (“atenolol” or “propranolol” or “carbamazepine” or “clofibric acid”) AND “fungus”), (“estrogens” or “estrogen” or “estrogenic”) AND “biosphere’s reserve”), (“pharmaceuticals” or “pharmaceutical”) AND (“river” or “water”)), (“wastewaters”) or (“water” or “river”) AND (“pollution” or “pollutant” or “pollutants” or “contaminant” or “contaminants” or “contamination”))

**Keywords limited to source titles:** “reverse osmosis”, “membrane bioreactor”, “nanofiltration”, “microfiltration”, “membrane fouling”, “nitrogen removal”, “nutrient removal”, “ultrafiltration”, “sequencing batch reactor”, “constructed wetlands”, “phosphorus removal”, “denitrification”, “wastewater”, “flocculation”, “membrane filtration”, “biological treatment”

**Source titles:** Ultrapure Water, Desalination and Water Treatment, Water Science and Technology, Water Research, Water Science and Technology: Water Supply, Water and Wastewater International, Journal/American Water Works Association, Water, Renewable Energy, Water Environment Research, Journal of Water Supply: Research and Technology - AQUA, Water 21, Water Engineering and Management

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