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Sistemas de Indicadores de Sustentabilidade: Análise Bibliométrica da produção científica

Sustainability Indicator Systems: Bibliometric Analysis of scientific production

Sistemas de Indicadores de Sostenibilidad: Análisis Bibliométrico de la producción científica

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PALAVRAS-CHAVE
Desenvolvimento Sustentável;
Indicadores de Sustentabilidade;
Sistemas de Indicadores de Sustentabilidade.

Resumo: O objetivo deste artigo é analisar bibliometricamente a produção científica sobre Sistemas de Indicadores de Sustentabilidade. Foram coletados artigos científicos publicados em Periódicos Nacionais e Internacionais, bem como Dissertações de Mestrado e Teses de Doutorado, que têm como objetivo de pesquisa propor ou aplicar Sistemas de Indicadores na mensuração da Sustentabilidade. O período da análise compreendeu os anos de 2006 a 2015. Trata-se de um estudo descritivo, de abordagem quantitativa, que utilizou como procedimento técnico a bibliometria sob o enfoque da cienciometria. Quanto aos principais resultados, verificou-se um crescimento na quantidade de trabalhos ao longo dos anos; o referido tema tem sido abordado pelas mais variadas áreas de conhecimento; a preferência dos autores é por pesquisas de natureza empírica; os Sistemas de Indicadores de Sustentabilidade utilizados nos trabalhos são modelados conforme o contexto em estudo; e a maior parcela dos trabalhos aborda a Triple Bottom Line (TBL) ou as três dimensões da Sustentabilidade (econômica, social e ambiental).

KEYWORDS
Sustainable Development; Sustainability Indicators; Sustainability Indicator Systems.

Abstract: *The purpose of this article is to carry out a bibliometric analysis of scientific production on Sustainability Indicator Systems. Scientific articles published in National and International Journals, as well as Master's Theses and Doctoral Dissertations, were collected. These collected works aimed to propose and apply Indicator Systems for measuring Sustainability. The proposed analysis was conducted between 2006 and 2015. The present work is characterized as descriptive and was developed by means of the quantitative approach. Bibliometrics was adopted as a technical procedure from the perspective of scientometrics. As far as the main results are concerned, there has been an increase in the quantity of studies over the years; the topic analyzed here has been discussed in various fields of knowledge; the authors have a preference for empirical studies; the Sustainability Indicator Systems discussed are shaped based on the context of each study; and most works discusses the Triple Bottom Line (TBL) and the three dimensions of Sustainability (economic, social and environmental).*

PALABRAS CLAVE
Desenvolvimiento Sustentable; Indicadores de Sostenibilidad; Sistemas de indicadores de Sostenibilidad.

Resumen: *Este artículo tiene como objetivo analizar bibliométricamente la producción científica sobre Sistemas de Indicadores de Sostenibilidad. Se recogieron artículos científicos publicados en Revistas Nacionales e Internacionales, Tesis de Maestría y Tesis Doctorales, que tienen como objetivo de investigación proponer o aplicar Sistemas de Indicadores en la medición de la Sostenibilidad. El período de análisis comprende los años 2006 a 2015. Se trata de un estudio descriptivo, con enfoque cuantitativo, que utilizó la bibliometría como procedimiento técnico bajo el enfoque de cienciometría. En cuanto a los principales resultados, se encontró que existe un incremento en la cantidad de trabajo desarrollado en los últimos 10 años; el tema referido ha sido abordado por las más variadas áreas de conocimiento; la preferencia de los autores es la investigación de carácter empírico; los Sistemas de Indicadores de Sostenibilidad utilizados en las obras se modelan de acuerdo al contexto en estudio; y la mayoría de los trabajos abordan el Triple Bottom Line (TBL) o las tres dimensiones de la Sostenibilidad (económica, social y ambiental).*

Introduction

Sustainability has become a greater concern due to the influence that today's society can have on future generations (Álvarez; Villardón; Rosa, 2015). The term Sustainable Development (SD) was primarily discussed by the World Conservation Union, which is also called International Union for the Conservation of Nature and Natural Resources (IUCN), in the World's conservation strategy in 1980. This document determines that in order for sustainable development to take place, some aspects must be taken into account, such as those regarding social and ecological dimensions, as well as economic factors, living and non-living resources and short-term and long-term advantages of possible actions. However, such a concept is mainly based on the environmental aspect, and the emphasis on the human aspect came to be only after its definition by the Brundtland Report, creating a balance between the economic, environmental and social dimensions (Bellen, 2004b).

Since the Brundtland report, several indices and indicators have been developed in this area, because the measurement of sustainability requires the creation of indicators as mentioned by Reid and Rout (2020). Some of the widely used ones nowadays have been adopted by the Organization for Economic Co-operation and Development - OECD, and the United Nations - UN (Álvarez; Villardón; Rosa, 2015).

Sustainability Indicator Systems are seen as tools consisting of one or more variables that, when combined in various ways, bear broader meanings about the phenomena. In that sense, they are regarded as essential instruments for guiding the action and subsidizing the monitoring and assessment of the progress achieved towards Sustainable Development - SD (IBGE, 2015). According to Tan et al. (2015), Sustainability Indicators are useful tools for summarizing and condensing complex data in relevant information, as well as monitoring the progress as far as performance is concerned over time.

The development of SIS is fundamental due to the necessity of simple assessment instruments that can capture positive and negative results of actions on a regular basis and allow for the identification of problems and potentialities in order for SD to be effective (Sales; Cândido, 2013).

SIS may be considered the best examples of tools that can assist in the permanent process of creation and recreation of local realities for the purpose of promoting SD. They are predominant for establishing diagnoses and prognoses, and for assessing the reality of places in order to promote the long-awaited quality of life, taking into account environmental conservation and social interaction (Kronemberger, 2011).

As noted by Bellen (2004b), SIS can contribute to an important management tool, either public or private, provided that they can guide and measure development. Nonetheless, it is necessary to get familiarized with the existing assessment tools, and the first step is to select the most important tools at international level.

In this context, the present study aims to conduct a bibliometric analysis of the scientific production on SIS. Initially, articles published in national and international journals were collected. The research objective of such studies was to propose and apply Indicator Systems in order to measure Sustainability in terms of environmental, economic and/or social dimensions. Subsequently, Master's Theses and Doctoral Dissertations from Brazilian Graduate Programs were collected. There were no restrictions regarding the fields of knowledge, provided that they shared the same research objective. The analysis took place between 2006 and 2015.

The theoretical contribution here lies on the lack of research that aim to propose and analyze the scientific production about this topic. As mentioned by Machado-da-Silva, Amboni and Cunha (1990), the best way to assess the evolution of knowledge about a particular topic is to analyze recent publications about it. Therefore, the purpose of this study is to present a scenario as far as studies about SIS are concerned by carrying out an analysis of most recent works. Since this topic is of great interest, the progress of future research relies on the understanding of the present stage of studies about it.

As noted by Reid and Rout (2020), there is no consensus in the literature over which indicators should be selected or developed, because this process is based on value judgement. In addition, there are no existing standard instruments where the score of different indicators can be incorporated and present an overview of the Sustainability of an industry, for example. Despite the limitations mentioned by the authors,

however, the SIS developed by governments, industries or Non-Governmental Organizations - NGOs help to assess whether a particular activity is sustainable or not. Thus, the analysis of the proposed scientific production can help to deepen the debate on SIS.

This study is structured as follows: introduction; theoretical framework, consisting of the theories that support it (SD or SIS); methodological procedures adopted; presentation and analysis of the results achieved; and, finally, conclusion.

Theoretical Framework

Sustainable Development - SD

Studies on SD emerged from the discussion about a new approach in which development was no longer strictly associated with economic growth. As stated by Hsu, Chang and Luo (2017), Gasbarro, Rizzi and Frey (2018) and Hojnik et al. (2020), one of the main challenges in the 21st century is sustainable development, which has become more relevant for both big and small organizations. Thus, this topic has quite recently aroused the interest of scholars and businessmen (Hojnik et al., 2020).

The approach was changed because of the fact that the economic growth of a particular society leads to various disadvantages to its development, which are mostly related to external social and environmental elements. In this context, and due to this imbalance, the concept of Sustainable Development was created in the 80's and means "meeting the needs of the present without compromising the ability of future generations to meet their needs". Such a concept was presented in the Brundtland Report, or (Our Common Future), and published by the World Commission on Environment and Development of United Nations in 1987 (Brundtland, 1991; Elkington, 1997; Brooks, 2010; Destatte, 2010; Hall; Daneke; Lenox, 2010; Karakosta; Askounis, 2010; Baumgartner, 2011; Laurence, 2011; Quental; Lourenço; Silva, 2011; Wallis; Graymore; Richards, 2011; Manteaw, 2012; Zaccai, 2012; Álvarez; Villardón; Rosa, 2015).

As noted by Kates, Parris and Leiserowitz (2005), the definition found in the Brundtland Report is seen as standard for SD due to its widespread use and frequency in the literature. Even though this brief definition does not clearly present environmental or developmental aspects, the subsequent paragraphs make it clear. As far as development is concerned, the authors also state that the Brundtland Report guarantees that human needs are basic and essential, that economic growth and equity for the sharing of resources with the underprivileged are necessary and must be promoted by means of effective participation of those involved. In terms of environment, the concept does not impose absolute limits, but limits to the current state of technology and the social organization on the use of environmental resources instead.

As mentioned by Hall, Daneke and Lenox (2010), the definition found in the Brundtland Report emphasizes the dynamic aspects of SD. In essence, the notion of this concept is that all natural systems have limits and that well-being requires living within such limits. In addition, Çubukçu (2010) states that the principle must be to protect the resources and use them effectively, so that future generational can benefit from them, too.

The interpretation of SD brought by the Brundtland Report leads to the understanding that the conventional economic imperative (increase of economic production) must be restrained in favor of the social imperatives (reduction of current and future human suffering) and ecological imperatives (environmental protection) (Bellen, 2004a). Therefore, this new definition has led to a relevant change in the sense that economic growth and the maintenance of social and environmental values would be incompatible (Laurence, 2011).

As noted by Buarque (2002), SD presupposes the organic articulation between three big sets, or dimensions, that are intertwined and share different characteristics and roles, but complement one another in the development process:

a) Increase in quality of life and social equity;
b) Efficiency and economic growth;
c) Environmental conservation.

Accordingly, there must be a balance between these three components; that is, Environmental Sustainability must first take place in order for Economic Sustainability to take place, too. As a consequence, Social Sustainability can also occur (Goosen, 2012).

As observed by Manteaw (2012), despite the popularity of the definition of SD created by the Brundtland Report, several other definitions have been created, which has made this concept

become multiform in its use. However, among the various approaches linked to SD, “Triple Bottom Line" (TBL), or People, Planet and Profit, is the one that has been emphasized due to its contributions to organizational studies, as well as because it has been widely discussed over the last few years. This approach aims to provide sustainable organizations with a new structure through which the focus should not only be on the economic issue, but also, and simultaneously, on social development and environmental preservation (Elkington, 1997; Brooks, 2010; Hall; Daneke; Lenox, 2010; Baumgartner, 2011; Laurence, 2011; Munck; Munck; Souza, 2011; Wallis; Graymore; Richards, 2011; Goosen, 2012).

The TBL approach was developed by Elkington (1997), considering he noted that organizations not only consume financial resources, but also environmental and social resources in order to carry out their activities. This tripartite notion suggests that the economic, environmental and social dimensions are equally relevant to the understanding of SD and must be discussed in tandem with one another (Elkington, 1997; Zago, 2007; Hall; Daneke; Lenox, 2010; Baumgartner, 2011; Wallis; Graymore; Richards, 2011).

Zago (2007) noted that these three dimensions can be represented in the organizational field based on the following terms: Economic Development, Social Responsibility and Environmental Management. Figure 1 illustrates the basic concept of Triple Bottom Line:

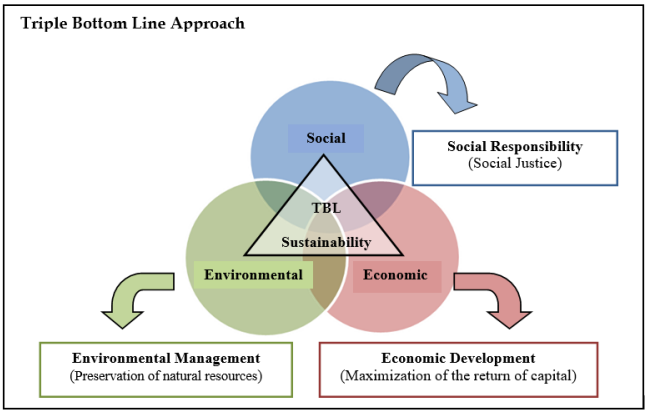

Figure 1 - Basic Concept of Triple Bottom Line
Source: Adapted from Zago (2007) and Wallis, Graymore and Richards (2011)

As shown in Chart 1, Munck, Munck and Souza (2011) presents the three dimensions, or pillars, that support SD from the perspective of a systemic approach. They see these pillars as subsystems that, on one hand, represent organizational capacities and, on the other hand, strategic objectives. According to the authors, each Sustainability consists of a whole, a system; in other words, Organizational Sustainability, which is regarded as a representation of the balance of subsystems or organizational actions.

Chart 1 - Pillars of Organizational Sustainability

Organizational Sustainability	
Economic Sustainability	It consists of topics such as: competitiveness, job offer, integration into new markets and long-term profitability. It is the main foundation of SD, since jobs are created through profit; hence, a variety of communities have better social conditions. When organizations achieve Economic Sustainability, they carry out their activities in a responsible and notorious way, resulting in financial and social return for all those involved.
Environmental Sustainability	It encompasses the prevention of impacts caused by the organization in natural systems. This pillar goes beyond conforming to governmental regulations and regulatory initiatives, such as recycling or efficient use of energy resources, since it does not exclude a comprehensive approach about the organizational operations. This approach is based on the assessment of the impacts caused by the products developed by the company, the daily processes and services in an organization, the elimination of unnecessary expenses and elevated emissions, and the reduction of practices that can affect the access of future generations to critical natural resources.
Social Sustainability	It embraces the management of the impact caused by the organization in social systems by means of its operational activities. In other words, it incorporates issues that are related to human development (education, training, health, occupational safety and development of competences), equity (fair wages and benefits, equal opportunities and no discrimination in the workplace), and ethics (human rights, cultural values, intergenerational justice and intragenerational justice).

Source: Adapted from Munck, Munck and Souza (2011).

Savitz and Weber (2007) argue that the TBL structure captures the essence of Organizational Sustainability by measuring the impact of operational activities in companies. A positive outcome leads to an increase in value for the company in terms of profitability and contribution to the wealth of shareholders, as well as social,

human and environmental capital. According to the authors, Sustainability is key to intelligent management, which can easily be avoided or seen as inevitable in a world where financial result is generally regarded as the only way to success.

Sustainability Indicator Systems - SIS

The operationalization of the SD concept requires the use of tools that provide information for the understanding of the reality investigated. As mentioned by Hojnik et al. (2020), measurement is required in order for something to be managed, and that also includes Sustainability. Therefore, the conception of Sustainability indicators is seen as a fundamental support for the measurement and establishment of actions that gravitate towards Sustainability by creating connections between the current stage of development and the sustainable scenario in the future (Ribeiro, 2002).

Wass et al. (2014) state that SIS are extremely important tools for assisting the SD in the decision-making process. Morioka and Carvalho (2016) noted that the efficient management of Sustainability requires the use of tools that can effectively measure, manage and communicate the sustainable actions that are performed. Moreover, these authors mention that in order for that to take place, a system for measuring performance must be created for the purpose of measuring the performance of these actions. Hojnik et al. (2020) state that these systems must capture issues related to economic, environmental and social elements in the company using qualitative, quantitative and comparative data over a period of time in order to determine the changes in time and among organizations of the same sector.

In that sense, the attempts to carry out a quantitative assessment of Sustainability can be found in several studies (Mikhailova, 2004). Nonetheless, the real need for consolidating SD indicators is found in Agenda 21, which was adopted in the United Nations Conference on Environment and Development. This event was held in Rio de Janeiro, in 1992, and aimed to transform SD into an acceptable global goal. After this conference, a five-year program for the development of appropriate instruments for those who are responsible for the making of decisions at a national level was adopted (Bellen, 2004b).

The search for SD indicators has become a widely discussed issue in the literatural at a national and international level. Consequently, the lack of methodologies for quantitative assessment has been seen as a critical issue to be tackled. As a result, in addition to the discussion about the concept of Sustainability, methodologies for the measurement of such a development were sought, measuring the level of development of a nation and the Sustainability of its socioeconomic and ecological systems (Mikhailova, 2004).

In that context, in order for indicators to be instruments of a process of change that leads to the SD concept, they must gather characteristics that enable them: to measure different dimensions so that the complexity of social phenomena can be understood; to have society participate in the process of establishment development; to communicate tendencies, subsidizing the decision-making process; and to associate variables, since reality is not linear nor one-dimensional (Guimarães; Feichas, 2009).

Some types of SIS have been used in order to identify and develop Sustainability indicators, but similarly to the SD concepts, the SIS used and developed are extremely diverse in terms of issues and dimensions (Bellen, 2002). From this perspective, Bellen (2004b) presents 18 SIS used for measuring Sustainability, which are listed in Chart 2:

Chart 2 - Main Sustainability Indicator Systems

Tool	Authorship
PSR (Pressure/State/Response)	OECD - Organization for Economic Cooperation and Development
DSR (Driving-Force/State/Response)	UN/CSD - United Nations Comission on Sustainable Development
GPI (Genuine Progress Indicator)	Cobb
HDI (Human Development Index)	UNDP - United Nations Development Programme
MIPS (Material Input per Service)	Wuppertal Institut - Germany
DS (Dashboard of Sustainability)	International Institut for Sustainable Development - Canada
EFM (Ecological Footprint Model)	Wackernagel and Rees
BS (Barometer of Sustainability)	IUCN - Prescott-Allen
SBO (System Basic	Bossel - Kassel University

Orientors)	
Wealth of Nations	(World Bank)
SEEA (System of Integrating Environment and Economic)	United Nations Statistical Division
NRTEE (National Round Table on the Environment and Economy)	Human/Ecosystem Approach - Canada
PPI (Policy Performance Indicator)	The Netherlands
IWGSD (Interagency Working Group on Sustainable Development Indicators)	US President Council on Sustainable Development Indicator Set
EE - Eco-Efficiency	WBCSD (World Business Council on Sustainable Development)
SPI (Sustainable Process Index)	Institute of Chemical Engineering - Graz University
EIP (European Indices Project)	Eurostat
ESI (Environmental Sustainability Index)	World Economic Forum

Source: Adapted from Bellen (2004b)

Martins and Cândido (2008) emphasize the following SIS: PSR (Pressure/State/Response), DS (Dashboard of Sustainability), BS (Barometer of Sustainability), DSR (Driving-Force/State/Response), DPSIR (Driving Force, Pressure, State, Impact, Response), HDI (Human Development Index), EFM (Ecological Footprint Model) and MEP (Monitoring Environmental Progress).

Whereas Mori and Christodoulou (2012) mention the following SIS: EFM (Ecological Footprint), ESI (Environmental Sustainability Index), DS (Dashboard of Sustainability), HDI (Human Development Index), GPI (Genuine Progress Indicator), Welfare Index, Index of Sustainable Economic Welfare, City Development Index, EVI (Environmental Vulnerability Index), EPI (Environmental Policy Index), LPI (Living Planet Index), EDP (Environmentally-adjusted Domestic Product), GS (Genuine Saving).

However, Bellen (2004b) observed that the most widely known SIS on an international scale are EFM (Ecological Footprint Method), DS (Dashboard of Sustainability) and BS (Barometer of Sustainability). The author states that, in spite of the diversity of Systems linked to the assessment of Sustainability, there are elements that require the development of studies, such as: the multidimensionality of the SD concept; the complexity that result from the gathering of variables that are not directly associated with one another; the issue of transparency in assessment systems; the existing value judgements and their balance in various systems; the type of a particular decision-making process, and the type of a particular variable (qualitative, quantitative, or both); etc.

After this brief theoretical discussion about the constructs that support the present study conceptually, the methodological procedures adopted in order to achieve the research objective will be presented in the next section.

Methodological Procedures

This study is descriptive and was developed by means of the quantitative approach as far as the objectives are concerned. Bibliometrics, which is a "... quantitative and statistical technique used for assessing the indices of production and dissemination of the scientific knowledge" (Araújo, 2006, p. 12), was used for the objective analysis of the scientific production on SIS.

Araújo and Alvarenga (2011) mention that, when applied for the purpose of assessing a scientific area, bibliometrics is regarded as scientometrics, since it analyzes the product that serves for reification of science itself; that is, scientific production. Thus, this study used bibliometrics from the perspective of the scientometric approach, because Articles published in Journals, as well as Dissertations and Theses from Graduate Programs, are products of scientific research.

Initially, Articles published between 2006 and 2015 in National and International Journals classified according to Qualis from CAPES (Coordination for the Improvement of Higher Education Personnel) in the quadrennium 2013-2016, were collected. These studies aimed to propose or apply Indicator Systems in order to measure Sustainability in the environmental, economic and/or social dimensions. Master's Theses and Doctoral Dissertations defended between 2006 and 2014 in Brazilian Graduate Programs, without any restrictions in terms of fields of knowledge, were collected subsequently.

The articles were collected from the following databases: Scielo (http://www.scielo.org) and ScienceDirect (http://www.sciencedirect.com).

The Dissertations and Theses were collected from the Brazilian Digital Library of Theses and Dissertations - BDTD on the website of the Brazilian Institute of Information in Science and Technology - IBICT (http://bdtd.ibict.br).

In the search box, the following keywords in Brazilian Portuguese were typed: “indicadores de sustentabilidade”, “sistema de indicadores de sustentabilidade” and “mensuração da sustentabilidade”, and their English equivalents: sustainability indicators, sustainability indicator systems and measurement of sustainability. The three main SIS mentioned by Bellen (2004b) were also used as keywords: ecological footprint method, dashboard of sustainability and barometer of sustainability. The titles were also typed, assuming that the keywords should be clear in them. However, the reading of the collected material was indispensable in order to verify whether the content had any relation to them. Data collection took place between June and July 2016. The sample consisted of 243 works among Articles, Dissertations and Theses.

In order to carry out the bibliometric analysis, a total of 05 relevant variables for this study were extracted. They were used in order to paint a picture of what was published in the Journals: selection of articles by journal and year of publication, research framework (theoretical or empirical research), SIS used and approach of the dimensions of Sustainability (environmental, economic and/or social dimmensions). As far as Dissertations and Theses are concerned, the following 06 variables were extracted: selection of Dissertations and Theses by Higher Education Institution - IES, by Graduate Program and by year of defense, research framework, SIS used and approach of the dimensions of Sustainability.

In order to contribute to the understanding and analysis of the results, a database on Microsoft Office Excel was created. This database consists of electronic spreadsheets where the studies were organized following the chronological order of publication of the Articles and defense of the Dissertations and Theses.

Presentation and Analysis of the Results

In this section, the results achieved in this study will be presented and analyzed in two subsections: 4.1 Analysis of Scientific Articles and 4.2 Analysis of Dissertations and Theses.

Analysis of Scientific Articles

The collection in the databases Scielo and ScienceDirect showed 153 results. A total of 35 were published in National Journals, and the other 118 were published in International Journals. The quantity of Articles selected by National journals are shown in table 1, whereas the quantity of Articles selected by International Journals are presented in table 2. It should be noted that the Journals were gathered based on the similarity of the quantitative element.

Table 1 - Quantity of Articles by National Journals

National Journals	Qty.
Engenharia Sanitária e Ambiental	05
Ambiente & Sociedade	04
Sociedade & Natureza	03
Agrociência / Cadernos de Saúde Pública / Gestão & Produção / Revista Árvore / Revista Escola de Minas / Revista Portuguesa e Brasileira de Gestão	02
Acta Amazonica / Ambiente Construído / Ciência e Agrotecnologia / Cuadernos de Desorrollo Rural / Jornal Brasileiro de Patologia e Medicina Laboratorial / Nova Economia / Produção / Revista Brasileira de Gestão Urbana / Revista de Administração Pública / Revista de Ciências Agrárias / Saúde e Sociedade	01

Source: Created by the Authors (2020)

Table 2 - Quantity of Articles by International Journals

International Journals	Qty.
Ecological Indicators	30
Journal of Cleaner Production	12
Ecological Economics / Renewable and Sustainable Energy Reviews	09
Environmental Impact Assessment Review / Procedia Social and Behavioral Sciences	05
Ocean & Coastal Management	04
Energy Policy / Journal of Environmental Management / Procedia CIRP / Science of The Total Environment	03
Applied Energy / Building and Environment / Cities / Ecological Modelling / Energy / Procedia Engineering	02

Agricultural Systems / Biomass & Bioenergy / Chemical Engineering Science / Communications in Nonlinear Science and Numerical Simulation / Current Opinion in Environmental Sustainability / Energy Economics / Energy for Sustainable Development / European Journal of Agronomy / Expert Systems with Applications / Food Policy / Forest Policy and Economics / Habitat International / Journal of Manufacturing Systems / Knowledge-Based Systems / Marine Policy / Pedosphere / Procedia Environmental Sciences / Rangeland Ecology & Management / Resources, Conservation and Recycling / Tourism Management	01

Source: Created by the Authors (2020)

As shown in Chart 3, the articles were found in 20 different National Journals in a variety of areas. The highest number of publications was found in Revista de Engenharia Sanitária e Ambiental (Journal of Sanitary and Environmental Engineering). The articles were found in 37 different International Journals, with emphasis on the Ecological Indicators, and the Journal of Cleaner Production, as shown in Chart 4. The former included 30 articles, whereas the latter included 12 articles.

Figure 2 presents the evolution of the quantity of Articles published between 2006 and 2015, as well as the percentage that each year represents in relation to the total number of studies.

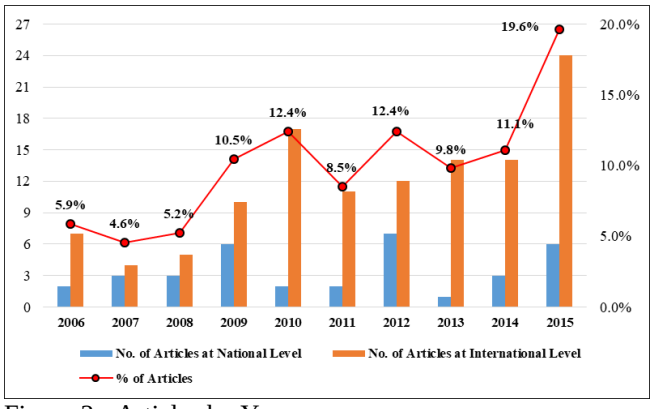

Figure 2 - Articles by Year
Source: Created by the Authors (2020)

Figure 2 shows the quantitative evolution of the total number of Articles, especially with respect to International Journals. In percentage terms, 19.6% of Articles were published in 2015, which is considered as a positive outcome, whereas only 4.6% of Articles were published in 2007.

Figures 3 and 4 show, respectively, the percentage selection of Articles published in National and International Journals in terms of research framework. Articles written in a theoretical essay format, proposals and applications of SIS and SIS modeling were categorized as theoretical Articles. Articles developed in a case study format and other applications of SIS were categorized as empirical Articles.

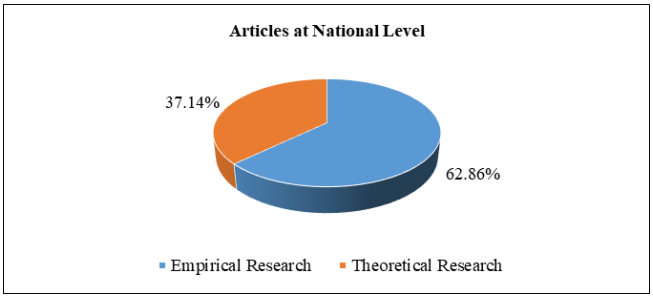

Figure 3 - Articles at National Level in terms of Research framework
Source: Created by the Authors (2020)

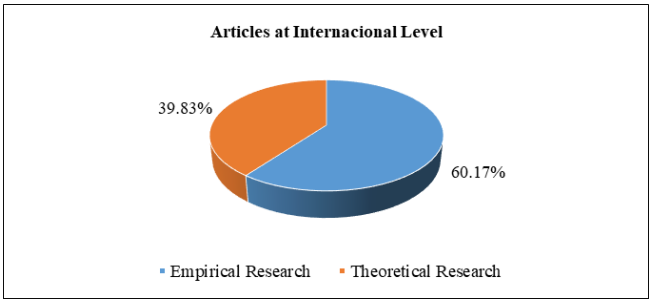

Figure 4 - Articles at International Level in terms of Research framework
Source: Created by the Authors (2020)

Figures 3 and 4 show the preference of the authors of the collected Articles published either in National or International Journals, considering the practical applicability of SIS, especially those written in a case study format. A total of 93 empirical Articles and 60 theoretical Articles were found.

The selection of Articles, in percentage terms, in relation to the SIS used is shown in Figure 5.

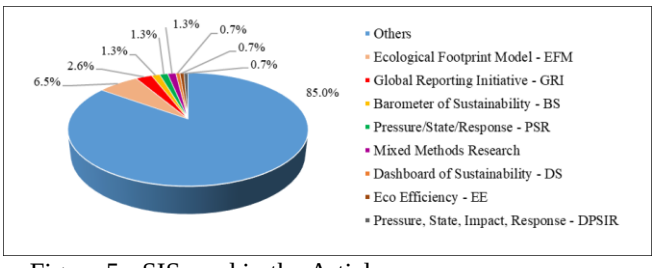

Figure 5 - SIS used in the Articles
Source: Created by the Authors (2020)

The amount of 85% of the Articles published either in National or International Journals, proposed and/or applied specific and adapted SIS, considering the context of the research. Among the Articles that used generic SIS, such as those mentioned by Bellen (2004b), Martins and Cândido (2008) and Mori and Christodoulou (2012), a total of 10 applications of the Ecological Footprint Method (EFM), 02 of the Barometer of Sustainability (BS), 02 of the Pressure/State/Response (PSR) Model, 01 of the Dashboard of Sustainability (DS), 01 of Eco-Efficiency, and 01 of the Driving Force, Pressure, State, Impact, Response (DPSIR) Model were found.

These findings corroborate the work of Ramos and Caeiro (2010), since they stated that there are several ways to measure Sustainability, which can provide governments, scholars and general public with useful ideas, even if they are presented in different ways.

Figure 6 presents the selection of Articles, in percentage terms, in relation to the approach of the dimensions of Sustainability and unveils that 61.4% discussed the three dimensions. This finding shows that the focus should not only be on the economic issue, but also, and simultaneously, on social development and environmental preservation (ELKINGTON, 1997; BROOKS, 2010; HALL; DANEKE; LENOX, 2010; BAUMGARTNER, 2011; LAURENCE, 2011; MUNCK; MUNCK; SOUZA, 2011; WALLIS; GRAYMORE; RICHARDS, 2011; GOOSEN, 2012). The OECD (2008) recommended in its report on SD that they should be analyzed in tandem with one another. Furthermore, 26.8% of the Articles focused on the environmental dimension only. Articles that discussed both social and economic dimensions simultaneously were not found.

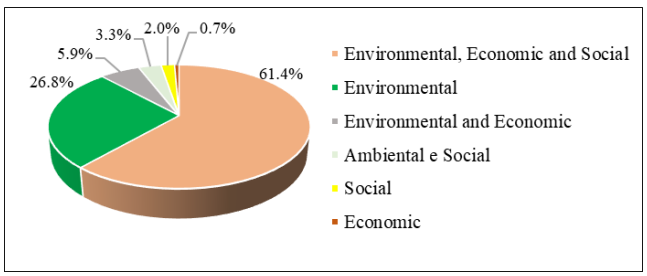

Figure 6 - Dimensions of Sustainability discussed in the Articles
Source: Created by the Authors (2020)

Analysis of Dissertations and Theses

The collection in the Brazilian Digital Library of Theses and Dissertations - BDTD showed 90 results; that is, a total of 26 Dissertations and 64 Theses were found. The quantity of studies selected by Higher Education Institution - IES is shown in table 3. The IES were organized based on the similarity of the quantitative aspect.

Table 3 - Quantity of Studies by IES

Institutions	Qty.
University of São Paulo (USP)	20
Federal University of São Carlos (UFSCAR)	07
Federal University of Ceará (UFC)	06
Federal University of Bahia (UFBA) / Federal University of Pernambuco (UFPE) / Federal University of Santa Catarina (UFSC) / São Paulo State University (UNESP)	05
Federal University of Paraíba (UFPB)	04
Rio de Janeiro State University (UERJ) / Federal University of Paraná (UFPR) / University of Brasília (UNB)	03
Santa Catarina State University (UDESC) / Federal University of Lavras (UFLA) / Federal University of Rio Grande do Sul (UFRGS) / Federal University of Rio Grande do Norte (UFRN) / Federal University of Viçosa (UFV) / Federal University of Technology – Paraná (UTFPR)	02
Regional University of Blumenau (FURB) / Pontifical Catholic University of Rio Grande do Sul (PUC-RS) / Mackenzie Presbyterian University / Federal Rural University of the Semi-Arid Region (UFERSA) / Federal University of Goiás (UFG) / Federal University of Ouro Preto (UFOP) / Federal University of Pará (UFPA) / Federal University of Pelotas (UFPEL) / Federal Rural University of Pernambuco (UFRPE) / University of Fortaleza (UNIFOR) / Nove de Julho University (UNINOVE) / University of the Rio do Sinos Valley (UNISINOS)	01

Source: Created by the Authors (2020)

As shown in Chart 5, Dissertations and Theses from 29 different IES were found. A total of 09 Dissertations and 11 Theses from USP defended in the time period previously mentioned were collected. Accordingly, most of these Dissertations and Theses were developed in USP.

The quantity of Dissertations and Theses selected by Graduate Programs, as well as the percentage that each Program represents in

relation to the total number of studies is shown in Figure 7.

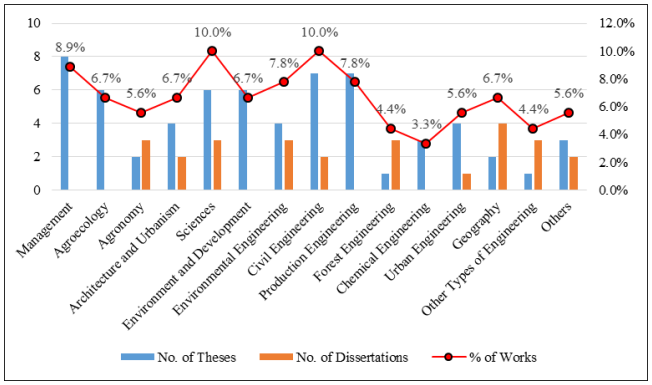

Figure 7 - Dissertations and Theses by Graduate Programs
Source: Created by the Authors (2020)

Figure 7 presents a diversity of areas from Graduate Programs, indicating the multidisciplinarity of the topic discussed here. The Graduate Programs in Sciences (10%), Civil Engineering (10%) and Management (8.9%) were found to have the highest percentage of works.

Figure 8 presents the evolution of the quantity of Dissertations and Theses defended between 2006 and 2015, as well as the percentage that each year represents in relation to the total number of studies.

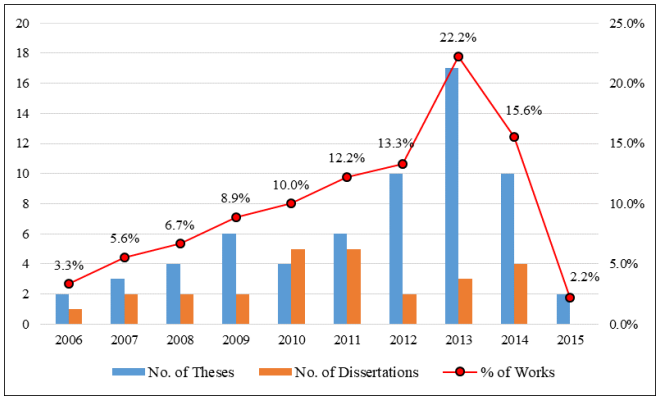

Figure 8 - Dissertations and Theses by Year
Source: Created by the Authors (2020)

The evolution of the quantity of the total amount of studies defended in the time period previously mentioned, whose peak was in 2013, is shown in Figure 8. On one hand, an increase in the number of Theses was observed. On the other hand, a considerable increase in the amount of Dissertations was not found. As a positive result, 22.2% of the total amount of works defended date from 2013. More specifically, a total of 17 Theses and 03 Dissertations were found. As a negative result, 2.2% of the total amount of works defended were from 2015. More specifically, a total of 02 Theses and not a single Dissertation were found.

Figures 9 and 10 show, respectively, the selection of Dissertations and Theses, in percentage terms, with respect to the research framework. Articles written in a theoretical essay format, proposals and applications of SIS and SIS modeling were categorized as theoretical Articles. Articles developed in a case study format and other applications of SIS were categorized as empirical Articles.

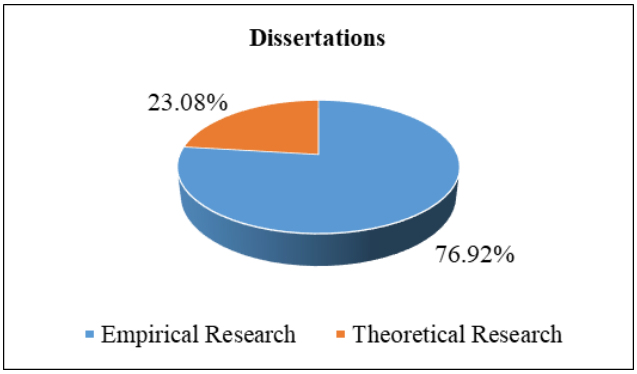

Figure 9 - Dissertations in terms of Research framework
Source: Created by the Authors (2020)

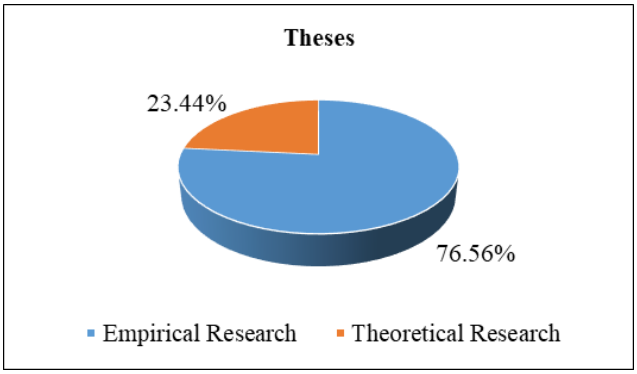

Figure 10 - Theses in terms of Research framework

Source: Created by the Authors (2020)

Figures 9 and 10 show that approximately 77% of the studies defended, among Dissertations and Theses, are seen as empiral research and only 23% as theoretical research, indicating the preference of the authors for the applicability of SIS, especially in a case study format. A total of 20 Dissertations and 49 Theses based on empirical research, and 06 Dissertations and 15 Theses consisting of theoretical content were found.

In percentage terms, the selection of studies concerning the SIS used is shown in Figure 11.

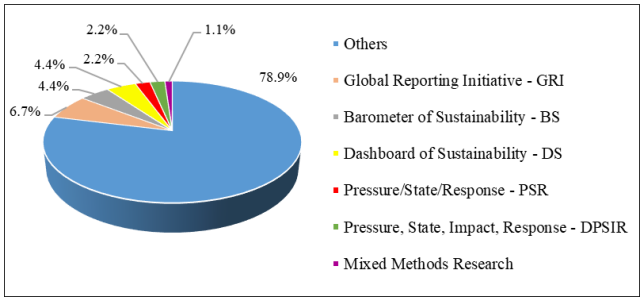

Figure 11 - SIS used in the Dissertations and Theses
Source: Created by the Authors (2020)

The total number of 71 Dissertations and Theses, which corresponds to 78.9%, proposed and/or applied specific and adapted SIS, considering the context of the research. Among the studies that used generic SIS, such as those mentioned in the Theoretical Framework section of this study, the following results were obtained: 04 applications of the Barometer of Sustainability (BS), 04 of the Dashboard of Sustainability (DS), 02 of the Pressure/State/Response (PSR) Model, 02 of the Driving Force-Pressure-State-Impact-Response (DPSIR) Model, and 01 application proposal of a System developed from a comparative analysis between the Barometer of Sustainability, the Dashboard of Sustainability and other SIS.

Finally, the selection of the studies in percentage terms in relation to the approach of the dimensions of Sustainability can be found in Figure 12.

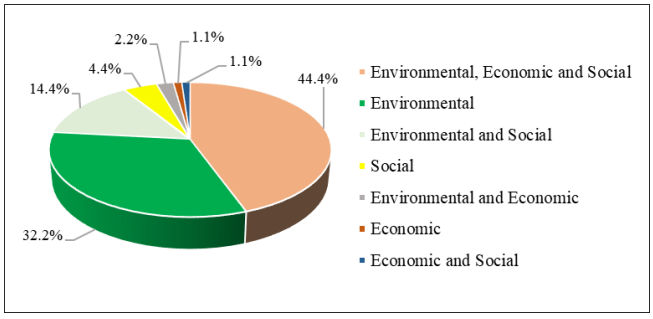

Figure 12 - Dimensions of Sustainability discussed in the Dissertations and Theses
Source: Created by the Authors (2020)

Figure 12 shows that 44.4% of Dissertations and Theses discussed the three dimensions of Sustainability. Subsequently, a total of 32.2% of the studies focused solely on the environmental dimension, which is similar to the findings of the analysis of the Articles, indicating the prominence of the tri-dimensional approach.

Conclusion

The present study aimed to carry out a bibliometric analysis of the scientific production on Sustainability Indicator Systems by collecting Scientific Articles, Dissertations and Theses whose major research objective was to propose or apply Indicator Systems for measuring Sustainability in the environmental, economic and/or social dimensions.

In the analysis of the results, an increase in the scientific production over the years in relation to the quantitative aspect was noted, especially in terms of Scientific Articles. The topic analyzed in this work has been discussed in Journals, as well as in Dissertations and Theses from Graduate Programs in various fields of knowledge. As far as the methodological framework of the collected studies are concerned, there is a higher number of empirical works, with the development of case studies and diverse applications.

Another relevant evidence is that the SIS that have been adopted for research are usually shaped by the particular context of the collected studies. Thus, not a single SIS was found to be the most widely used system. Furthermore, the approach of the three dimensions of Sustainability (TBL) was emphasized in the collected works, reinforcing that the focus should not only be on the economic issue, but also, and simultaneously, on social development and environmental preservation. As observed by Hojnik et al. (2020), most of the SIS follows the TBL concept, and the same was also noted in this study.

The topic analyzed here was more commonly found in International Journals than in National Journals, considering the set period of time previously mentioned, as shown in the quantitative data of the collected Articles (118 vs 35). However, this statement can only be validated by collecting studies from other databases. For future research, it is recommended that the collection for the purpose of carrying out a bibliometric analysis on SIS can include other databases, such as Spell, Scopus and Web of Science.

In terms of Dissertations and Theses, there was a reduction in the quantity of studies defended from 2013, indicating a negative result in 2015, with only 2.2% of works defended. Such an evidence is linked to delays in the publication of

Dissertations and Theses in the database of the Brazilian Digital Library of Theses and Dissertations (BDTD). For future research, it is necessary that data are collected from other databases, such as the Database of Theses and Dissertations from CAPES (Coordination for the Improvement of Higher Education Personnel), in order to validate the evidence found in this study.

Finally, further bibliometric analysis can be conducted by selecting other variables, such as: the research approach (qualitative, quantitative, quali-quantitative approaches), the data collection instrument adopted, the data analysis technique used, and the productive sector where the research was developed.

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