Paraconsistent Annotated logic applied to Academic Entrepreneurship: A Systematic Literature Review

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Abstract

This work conducted a literature review on Paraconsistent Annotated Logic (PAL) to search for evidence of its use in the field of Academic Entrepreneurship. The aim was to identify models that evaluate scientific products likely to have intellectual property protection rights (IPR), the potential to become an academic spin-off, or support a technology transfer process. The references were searched in the Web of Science database by using the keyword' paraconsistent logic' and selecting articles published in peer-reviewed journals from 1980 to 2021, which returned 460 articles, 135 journals, and 537 authors. The metadata analyses were carried out using Biblioshiny (Bibliometrix R package), the systematic scoping review using the PRISMA extension for Scoping Reviews, and the bibliometric analysis was performed over documents, authors, and sources. As result, 20 articles associated with PA were selected for systematic review, of which 5 were identified as dealing with PAL-based models. Although none of the models addressed PAL applied to scientific products with IPR, a study highlighted the possibility of adapting decision-making models to evaluate the IP developed in the academic environment.

Keywords: academic entrepreneurship; bibliometric; paraconsistent annotated logic; systematic review; PRISMA ScR.

Introduction

The increasing Patenting and Licensing Activity from the academic community has suggested a shift in the main role and funding structure of universities, that aims to exploit economic opportunities and be in charge of their scientific technology commercialization (Allen; Link; Rosenbaum, 2007). Besides the teaching and research activities, professors, students, and scientist has dedicated part of their time to supporting a business model based on scientific information and building new networks and licensing agreements with external stakeholder, governments, and the industry (Allen; Link; Rosenbaum, 2007). Such collaborations have led the universities to assume a third mission and emerge as entrepreneur institutions, being more active generators and disseminators of valuable knowledge at a local and global level (Chapman et al., 2011). Not surprisingly, it can be noted in the academic environment a concomitant improvement of traditional activities with intensive development of ventures related to the creation of academic spin-offs companies and technology transfer officers, knowledge transfer, training, consultancy and university-based startups, which has a great social and economic impact (Carlsson et al., 2009).

In this context, over the years numerous published papers focused on identified patterns of university-industry interactions and understood the critical issues on academic entrepreneurship, which also influenced recent literature reviews on AE. Some of these reviews identified theoretical models that deal with technology transfer and empirically assess the whole landscape of academic entrepreneurship, however it was not found evidence of models evaluating the potential of scientific products likely to have intellectual property protection rights (IPR), to become an academic spin-off (ASO) or to go through a technology transfer process (Domingues et al., 2022). Thus, the present paper aims to analyze relevant articles on the topic and conduct a systematic review of the literature to search for evidence of the Paraconsistent Annotated Logic (PAL) as the basis to evaluate the viability of AE models.

The Paraconsistent Logic (PL) is a new logical view that deals with inconsistency, ambiguity, and uncertainty in a discriminating way without exploding into the so-called triviality, or the necessity of discarding data. Unlike classical logic, restricted to binary information where in all contradictory proposition entails an indefinite condition (trivialization), the paraconsistent logic is subjacent to formalizing the inconsistent but non-trivial theories and is able to process real situations.

First published in the article by Da Costa and Wolf (1980), the studies in paraconsistent logic and its theoretical concepts have been extended to support real-world information systems and data sets since the classical logic principles have limited application. In this context, from the PL family, the Paraconsistent Annotated Logic (PAL) has been

employed in the areas such as Computing, Robotics, and Artificial Intelligence (Abe, 2011; Costa et al., 1999).
Da Silva Filho (2006), proposed an innovative method to provide a practical application of the paraconsistent logic through the extension called paraconsistent annotated logic with annotation of two values (PAL2v). The non-classic logic PAL2v is capable of handling contradictory signals to deal with inconsistencies not covered by classical logic, where in through an evidence-based approach, the problems caused by contradictory and paracomplete circumstances can be treated by keeping close to reality. Therefore, the method can be implemented by software or hardware in the fields of Expert Systems, Neural Networks, Robotics, and Artificial intelligence.

2. Methods

2.1 Quantitative Tools

The bibliometric analysis has been applying a wide variety of approaches and methods to track the magnitude and quality of scientific production and to map the extensive literature on a given knowledge area. Through bibliometrics is possible to use quantitative indicators, statistics operations, and citations patterns to manage the massive data and evaluate the development, maturity, main authors, concept and intellectual maps, and tendencies of multiple disciplines and their scientific publications, that includes Journal Articles, Proceeding Papers, Books Chapters, and others.

For being predominantly quantitative, this study should be conducted based on a predetermined workflow and solid analysis parameters that enables the measurement and quantification of the results with greater precision while minimizing the possible distortions during the data analysis and interpretation stage and leading to more accuracy when drawing inferences (Ellegaard, 2018). Hence, the use of bibliometric tools stands out as a logical and natural pathway to accomplish our study goals.

The Biblioshiny (Bibliometrix for no coders) package of R-Studio, a web interface of Bibliometrix An R-tool for comprehensive science mapping analysis, was used as a tool to select the relevant articles on the proposed topic and to carry out the bibliometric analysis, determining Most Cited Authors, Most Productive Authors, Author Impact, Corresponding Author's Country, Author Institutional Affiliation, Most Influential Authors on the specific research field, Most Common Document Type, Mean Age of References, Obsolescence of the literature, Geographic origin of the bibliography, Institutional Affiliations of the Bibliography, Most Cited Journals, and set of journals on models based on paraconsistent logic to evaluate the viability of AE (Abramo; D'angelo, 2014; Aria; Cuccurullo, 2019; Broadus, 1987). The Bibliometrix package provides a set of tools designed for quantitative studies in the field of both bibliometric and scientometrics (Aria; Cuccurullo, 2017; R Foundation, 2021; Mcneill, 2020).

2.2 Protocol

The study was performed following the PRISMA protocol (Liberati et al., 2009; Moher et al., 2009), adapted from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Review (PRISMA-ScR) (Porto; Gurgel, 2018; Tricco et al., 2018a, 2018b).

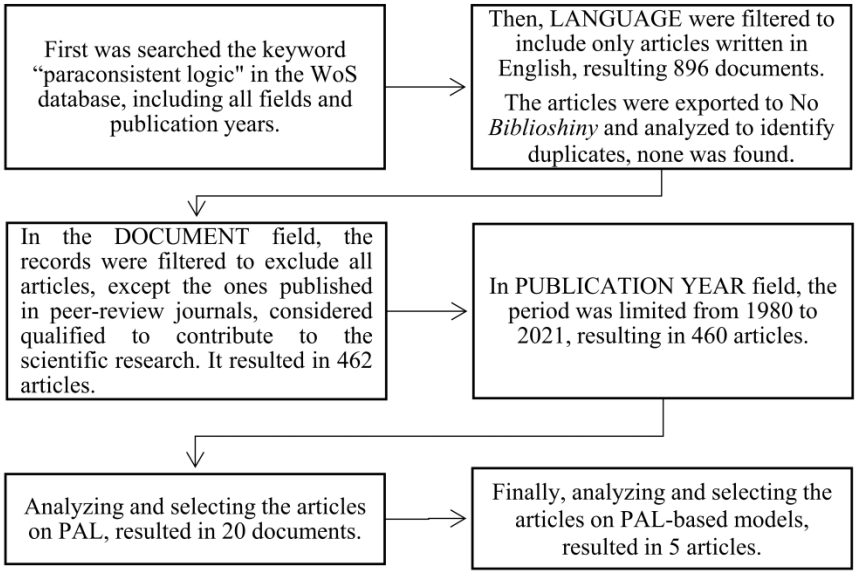
2.3 Eligibility criteria

The examined references were searched and retrieved from the Web of Science database. At first, was searched indexed papers containing the term 'paraconsistent logic' (All Fields), written in English, published in peer-review journals up to 2021 and excluding Document Types: Proceeding Paper, Book Review, Early Access, Meeting Abstract, Biographical-Item, Editorial Material, and Review. Next, the articles were filtered by including more two terms: 'Annotated' (Search within all fields), and then 'Model' (Search within all fields) (Tricco et al., 2018b, p. 22).

3. Results and discussion

For better comprehension of this work, the analysis and respective results are described in three parts. The eligibility criteria with reasons for exclusions or inclusion at each stage are illustrated as a flowchart in Figure 1. The first part was focused on the bibliometric metadata analysis of the scientific production related to Paraconsistent Logic. The search for articles written in English on 'paraconsistent logic' indexed in the WoS database (All Fields, All Document Type, and All Publication Year) resulted in 896 records. Thereafter, such papers were limited to only covering the period from 1980 to 2021 and Articles as document type, which then resulted in 460 peer-reviewed articles published in 131 journals and 520 authors identified (Collection 1). The second part intended to carry out a systematic literature review on Paraconsistent Annotated Logic. Thus, Collection 1 was filtered by including the term 'annotated' as a keyword and then resulted in 20 records (Collection 2). Finally, the third part was developed to perform a scoping review of the articles present in Collection 2 that were related to PAL-based models, which were selected by adding "model" in the query (Collection 3).

Figure 1. Flowchart of studies selected, evaluated for eligibility and included in the systematic literature review on Paraconsisted Annotated Logic. [1]



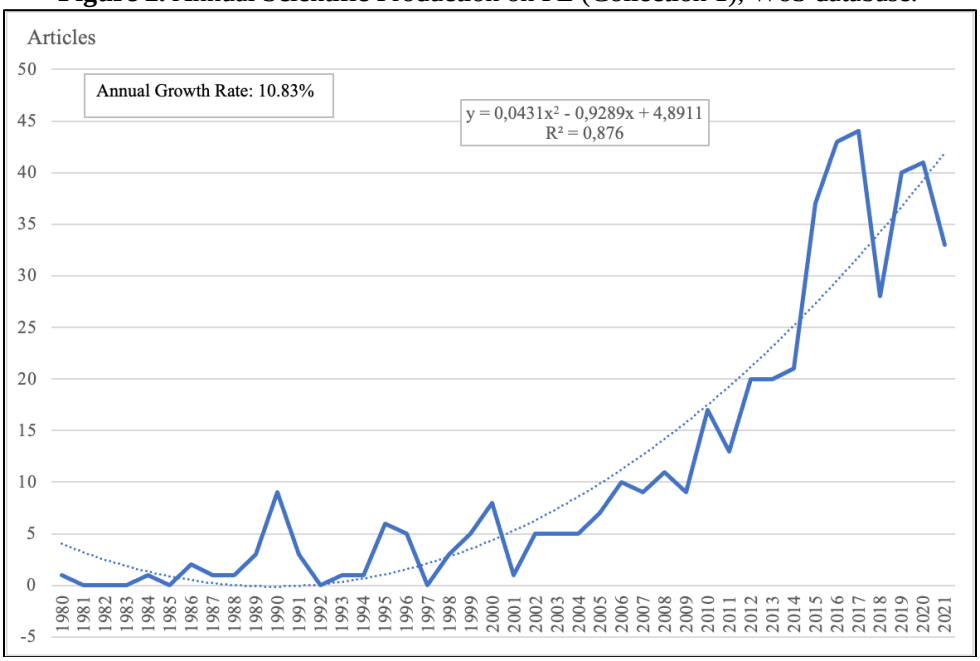
Source: Elaborated by the authors (2022). [1]Each flowchart step indicates the reasons for document exclusions considering the systematic literature review on academic entrepreneurship.

3.1 The scientific production related to Paraconsistent Logic

The main information on the Collection 1 is present in Table 1 and the evolution of scientific outputs over the years, which recorded an Annual Growth Rate of 10.83% and is represented by the Second-Degree Polynomial $y=0.426x^2-0.8958x+4.2988$, can be observed in Table 2 and Figure 2.

The Average Citation per Year on PL followed a non-continuous and unregular increasing trend with remarkable peaksin 1989, 1991, 1995, 2007, and 2013 (Table 3 and Figure 3).

Figure 2. Annual Scientific Production on PL (Collection 1), WoS database.



Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix, *Dataset/Annual Scientific Production.*

Table 1. Main Information on PL (Collection 1), WoS database.

Description		**Results**
Main Data Information	Timespan	1980:2021
	Sources (Journals)	131
	Average years from publication	7.9
	Average citations per document	7.88
	Average citations per year per	0.8922
	References	8348
Document Information	Articles	460
	Keywords Plus (ID)	250
	Author's Keywords (DE)	1094
Authors	Authors	520
	Author Appearances	919
	Authors of single-authored docs	142
	Authors of multi-authored docs	378
Authors Collaboration	Single-authored documents	210
	Documents per Author	0.885
	Authors per Document	1.13
	Co-Authors per Documents	2
	Collaboration Index	1.51

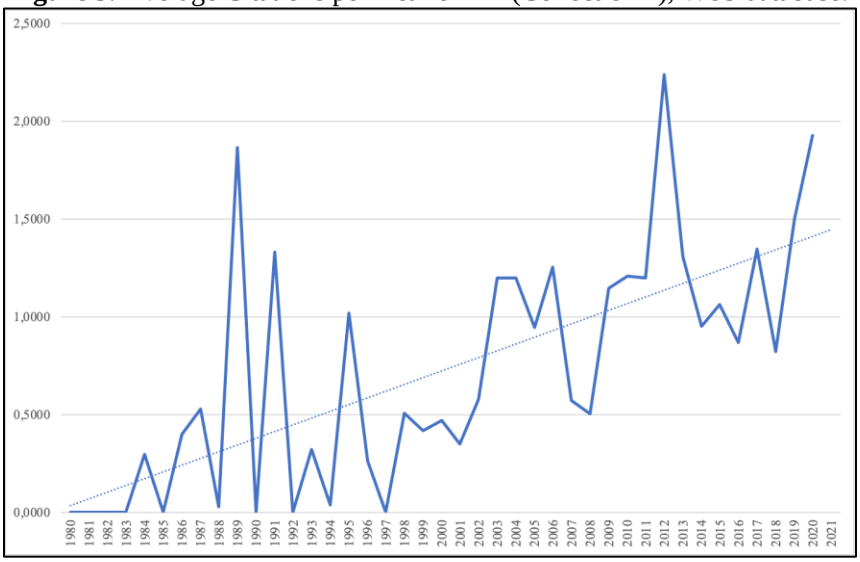
Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix

Table 2. Annual Scientific Production on PL (Collection 1), WoS database.

Year	Articles	Year	Articles	Year	Articles	Year	Articles	Year	Articles
1980	1	1990	0	2000	8	2010	17	2020	41
1981	0	1991	3	2001	1	2011	13	2021	33
1982	0	1992	0	2002	5	2012	20		
1983	0	1993	1	2003	5	2013	20		
1984	1	1994	1	2004	5	2014	21		
1985	0	1995	6	2005	7	2015	37		
1986	2	1996	5	2006	10	2016	43		
1987	1	1997	1	2007	9	2017	44		
1988	1	1998	3	2008	11	2018	28		
1989	3	1999	5	2009	9	2019	40		
Total	9		24		70		283		74

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix

Figure 3. Average Citations per Year on PL (Collection 1), WoS database.



Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix, *Dataset/Average Citations per Year.*

Table 3. Average Citations per Year on PL (Collection 1), WoS database.

Year	N[1]	TC /Art[2]	TC /Art[3]	[4]CY	Year	N	TC /Art	TC /Art	CY
1980	1	0.0000	0.0000	41	**2001**	1	7.0000	0.3500	20
1981	0	0.0000	0.0000	0	**2002**	5	11.0000	0.5789	19
1982	0	0.0000	0.0000	0	**2003**	5	21.6000	1.2000	18
1983	0	0.0000	0.0000	0	**2004**	5	20.4000	1.2000	17
1984	1	11.0000	0.2973	37	**2005**	7	15.1429	0.9464	16
1985	0	0.0000	0.0000	0	**2006**	10	18.8000	1.2533	15
1986	2	14.0000	0.4000	35	**2007**	9	8.0000	0.5714	14
1987	1	18.0000	0.5294	34	**2008**	11	6.5455	0.5035	13
1988	1	1.0000	0.0303	33	**2009**	9	13.7778	1.1481	12
1989	3	59.6667	1.8646	32	**2010**	17	13.2941	1.2086	11
1990	0	0.0000	0.0000	0	**2011**	13	12.0000	1.2000	10
1991	3	40.0000	1.3333	30	**2012**	20	20.1500	2.2389	9
1992	0	0.0000	0.0000	0	**2013**	20	10.4500	1.3063	8
1993	1	9.0000	0.3214	28	**2014**	21	6.6667	0.9524	7
1994	1	1.0000	0.0370	27	**2015**	37	6.3784	1.0631	6
1995	6	26.5000	1.0192	26	**2016**	43	4.3488	0.8698	5
1996	5	6.6000	0.2640	25	**2017**	44	5.3864	1.3466	4
1997	0	0.0000	0.0000	0	**2018**	28	2.4643	0.8214	3
1998	3	11.6667	0.5072	23	**2019**	40	3.0000	1.5000	2
1999	5	9.2000	0.4182	22	**2020**	41	1.9268	1.9268	1
2000	8	9.8750	0.4702	21	**2021**	33	0.3030		0

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix,
[1] Number of Articles; [2]Mean TC/Article; [3]Mean TC/year; [5]Citable years.

Table 4 presents the top 20 Most Relevant Sources in the PL collection, of which 5 have stood out with more than 20 published articles: *Logic Journal of The Igpl* with 37, *Journal of Philosophical Logic* with 34, *Journal of Logic and Computation* with 33, *Synthese* with 25 and *Studia Logica* with 23. Table 5 shows the Most Local Cited Sources related to PL, which can be noticed that seven 7 of them had more than 200 citations: *J Philos Logic*with 372, *J Symbolic Logic*with 319, *Studia Logica* with 283, *Artif Intell* with 266, *Stud Logica* with 283, *J Logic Comput* with 211 and *Lect Notes Artif Int* with 207.

Table 4. Most Relevant Sources on PL (Collection 1), WoS database.

Sources	Articles
Logic Journal of The Igpl	37
Journal of Philosophical Logic	34
Journal of Logic and Computation	33
Synthese	25
Studia Logica	23
Logica Universalis	18
Logic and Logical Philosophy	16
Review of Symbolic Logic	16
Logique et Analyse	10
History and Philosophy of Logic	9
Australasian Journal of Logic	8
Journal of Applied Logics-Ifcolog Journal of Logics and Their Applications	8
Mathematical Logic Quarterly	8
Fundamenta Informaticae	7
Australasian Journal of Philosophy	6
Journal of Applied Logic	6
Notre Dame Journal of Formal Logic	6
Annals of Mathematics and Artificial Intelligence	5
International Journal of Approximate Reasoning	5
Reports on Mathematical Logic	5

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix.

Bradford's law (Bradford, 1948) of Scattering of Scientific papers is applied to identify how the literature in a given field is distributed throughout the journals by dividing the collection into three groups, each one containing about 1/3 of all articles. Zone 1 contains the most frequently cited journals and therefore, represents the most important set of journals likely to be of interest to researchers when selecting articles on the subject. For the present collection on PL, the core zone accounted for 5 journals: *Logic Journal of The Igpl, Journal of Philosophical Logic, Journal of Logic And Computation, Synthese, Studia Logica* (Table 6 and Figure 4).

Table 5. Most Local Cited Sources on PL (Collection 1), WoS database.

Sources	Articles	Sources	Articles
J Philos Logic	372	Notre Dame Journal of Formal Logic	143
J Symbolic Logic	319	Log Anal	136
Studia Logica	283	Log J Igpl	132
Artif Intell	266	Synthese	117
Stud Logica	231	Modern Uses Multiple	100
J Logic Comput	211	Paraconsistent Logic	97
Lect Notes Artif Int	207	Thesis	93
Lect Notes Comput Sc	188	J Appl Logic	89
Hdb Philos Logic	173	Theor Comput Sci	86
Notre Dame J Form L	151	Mind	84

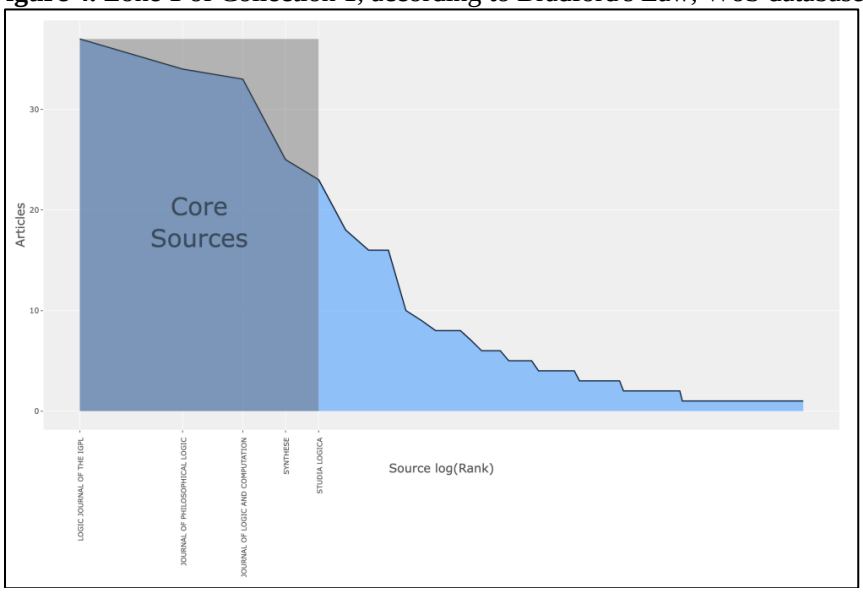
Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix.

Table 6. Zone of Collection 1, according to Bradford's Law, WoS database**.**

Source	Rank	Freq	Cum Freq
Logic Journal of The Igpl	1	37	37
Journal of Philosophical Logic	2	34	71
Journal of Logic And Computation	3	33	104
Synthese	4	25	129
Studia Logica	5	23	152

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix.

Figure 4. Zone 1 of Collection 1, according to Bradford's Law, WoS database.



Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix, *Sources/Bradford's Law.*

The Bibliometric Impact of each Source was measured by the citation metrics of the published articles, h- and m-index proposed by Hirsch (2005) and g-index proposed by Leo Egghe (2006), as these metrics highlight the contribution and recognition of a journal within the academic community. The journals in PL collection were ranked in decreasing order of h-index and six of them achieved an h-index higher than 7: *Journal of Philosophical Logic, Journal of Logic And Computation, Studia Logica, Logic Journal of The Igpl, Synthese, Review of Symbolic Logic* (Table 7).

Table 7. Source Local Impact on PL (Collection 1), WoS database.

N.	Source	h_index	g_index	m_index	TC	NP	PY_start
1	Journal of Philosophical Logic	14	23	0.368	546	34	1984
2	Journal of Logic And Computation	11	22	0.423	501	33	1996
3	Studia Logica	9	15	0.750	246	23	2010
4	Logic Journal of The Igpl	7	12	0.368	195	37	2003
5	Synthese	7	10	0.194	133	25	1986
6	Review of Symbolic Logic	7	13	0.583	176	16	2010
7	Logica Universalis	5	6	0.714	55	18	2015
8	Logic And Logical Philosophy	4	7	0.571	57	16	2015
9	Australasian Journal of Philosophy	4	6	0.400	42	6	2012
10	Journal of Applied Logic	4	6	0.333	42	6	2010
11	Mind	4	4	0.200	57	4	2002
12	History And Philosophy of Logic	3	4	0.125	24	9	1998
13	Mathematical Logic Quarterly	3	3	0.115	15	8	1996
14	Fundamenta Informaticae	3	7	0.188	59	7	2006
15	International Journal of Approximate Reasoning	3	5	0.333	35	5	2013
16	Soft Computing	3	5	0.214	32	5	2008
17	Information Sciences	3	4	0.429	31	4	2015
18	Journal of Automated Reasoning	3	3	0.111	54	3	1995
19	Logique Et Analyse	2	4	0.133	21	10	2007
20	Australasian Journal of Logic	2	3	0.286	15	8	2015

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix.

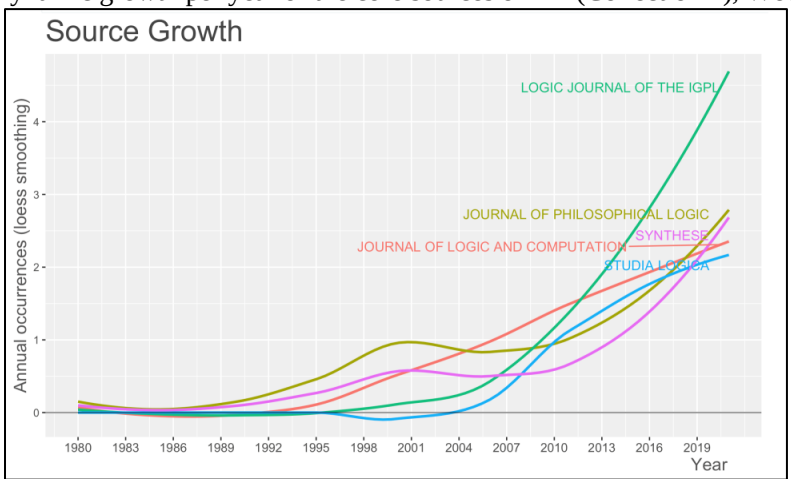
The analysis of the dynamic growth per year of the core sources (Zone 1 from Bradford's Law) (Bradford, 1948), showed a mutual increase of the journals publishing on PL up to 2012, wherein from 2013 the *Logic Journal of the IGPL stands out from the others* (Figure 5).

In terms of productivity and influence, the authors were analyzed by the following metrics: Most relevant authors, Most Local Cited Authors, Author's production per year, Lotka's law, Author local impact (h-index), Most Relevant Affiliations and Corresponding Author's Country.

The twenty most influential authors in the PL field are present in Table 8, where Kamide high lights as the most relevant author with 29 publications, followed by Avron and Coniglio with 14, Abe and Robles with 11 and Carnielli with 10. The most cited authors included: Abe JM with 145 citations, Subrahmanian VS with 142 citations, Avron A with 139 citations, Da Costa NCA with 102 citations, Arieli O with 100 citations, and Kamide N with 80 citations. Further, it is interesting to observe that although Abe has been the most cited author, he had the second lowest number of fractioned articles, which indicates the quality of his published work (Table 9).

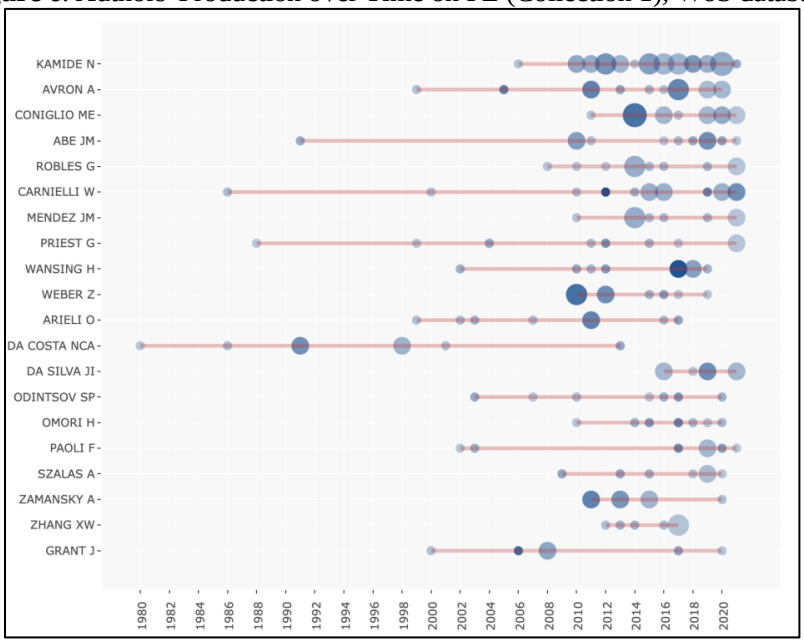
By analyzing the Authors' Production over time, it is possible to notice that Da Costa not only was the first author to publish about PL, in 1980, but also kept a constant production in the field in the following decades, most of the time in collaboration with other authors (Figure 6).

Figure 5. Dynamic growth per year of the core sources on PL (Collection 1), WoS database.



Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix, *Sources/Source Local Impact.*

Figure 6. Authors' Production over Time on PL (Collection 1), WoS database.



Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix, *Authors' Production over Time*.

Table 8. Most Relevant Authors on PL (Collection 1), WoS database**.**

N.	Authors	Articles	Articles Fractionalized
1	Kamide N	29	25.00
2	Avron A	14	8.33
3	Coniglio ME	14	5.33
4	Abe JM	11	2.49
5	Robles G	11	6.33
6	Carnielli W	10	4.42
7	Mendez JM	9	4.33
8	Priest G	9	7.09
9	Wansing H	9	5.00
10	Weber Z	9	6.33
11	Arieli O	8	5.17
12	Da Costa NCA	8	3.33
13	Da Silva JI	7	1.36
14	Odintsov SP	7	5.00
15	Omori H	7	4.00
16	Paoli F	7	4.08
17	Szalas A	7	3.58
18	Zamansky A	7	2.42
19	Zhang XW	7	3.62
20	Grant J	6	3.25

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix.

Lotka's law (Lotka, 1926) was calculated to examine the productivity patterns of authors on PL. This metric is represented by the relation $y=C/x^n$, where: x is the number of publications, y is the relative frequency of authors with x publications, and n and C are constants. Once for the original dataset, the value of n was estimated as ≈2 the law is known as the 'inverse square law of scientific productivity' and means that nearly 60% of all contributors will make only a single publication. For this collection, the values of C and n were respectively 0.4068 and 1.879 which is close to the generalized form of Lotka's Law. Hence, it was found that 368 authors wrote one single article and one author appeared in 29 articles. (Figure 7 and Table 10).

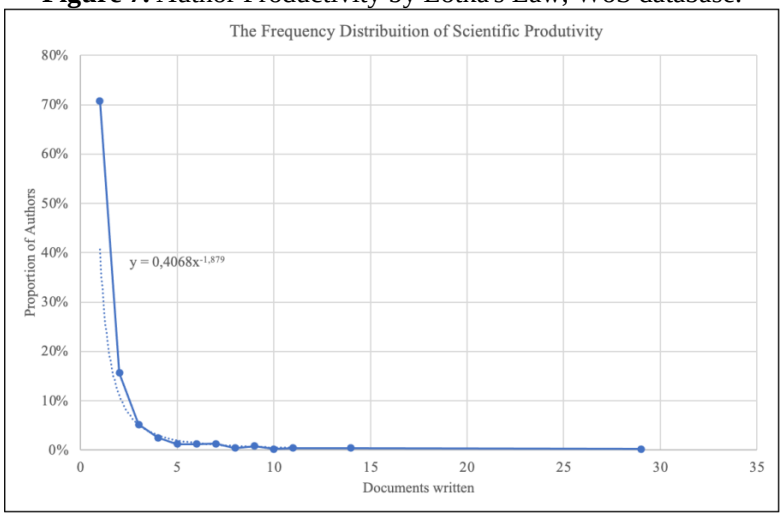
The h-, m- and g-index established by Hirsch (2005) and Egghe (2006) are measures of academic achievement that assess the authors' impact by accounting for their citations and publications, thus authors are ranked according to their contribution within the academic community. In this PL collection, the authors were listed in descending order of h-index followed by g-index and later m-index and the most outstanding were Kamide N, Arieli O, Avron A, Da Costa NCA, Wansing H, Weber Z, Hunter A and Abe JM (Table 11).

Table 9. Most Local Cited Authors on PL (Collection 1), WoS database.

Author	Local Citations
Abe JM	145
Subrahmanian VS	142
Avron A	139
Da Costa NCA	102
Arieli O	100
Kamide N	80
Hunter A	78
Nakamatsu K	77
Carnielli WA	73
Zamansky A	71
Lin Zq	62
Marcos J	61
Blair HA	58
Hitzler P	48
Ma Y	45
Wansing H	42
Szalas A	41
Vago C	38

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix.

Figure 7. Author Productivity by Lotka's Law, WoS database.



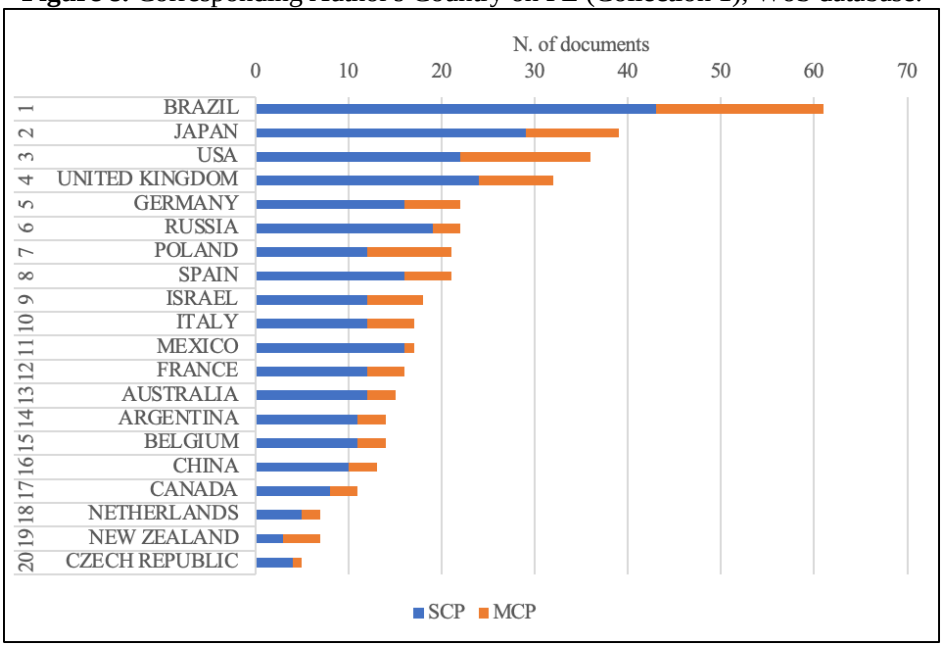
Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix,
Author Productivity through Lotka's Law.

The Institutions with the highest number of contributions in terms of published articles were: the University of Campinas with 51, the University of São Paulo with 22, Teikyo University with 19, Ruhr University Bochum and Tel Aviv University with 16, University Maryland with 13, University Melbourne with 12, and University Paulista and University Warsaw with 10 (Table 12).

Regarding the Author's Country, the most relevant countries in numbers of published articles were: Brazil with 61, Japan with 39, the USA with 36, the United Kingdom with 32, and Germany with 22 (Table 13 and Figure 8). Meanwhile, the top 5 most cited countries comprise, in this order: the USA, Brazil, the United Kingdom, Israel, and Japan (Table 14).

It should be mentioned that the top nine most relevant affiliations including three Brazilian institutions, the 1st and 2nd position (publics) and ninth (private), and being Brazil the most relevant country, it may be because Brazil is the native country of Da Costa, one of the first authors to publish on PL.

Figure 8. Corresponding Author's Country on PL (Collection 1), WoS database.



Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix, *Corresponding Author's Country*.

Table 10. Author Productivity by Lotka's Law, WoS database

No. of written articles	N. of Authors	Proportion of Authors
1	368	0.708
2	81	0.156
3	27	0.052
4	13	0.025
5	6	0.012
6	6	0.012
7	7	0.013
8	2	0.004
9	4	0.008
10	1	0.002
11	2	0.004
14	2	0.004
29	1	0.002

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix, *Author Productivity through Lotka's Law*.

The most cited papers on WoS database (Table 15), were: *Paraconsistent logic programming* (Blair; Subrahmanian, 1989), *Tolerant, Classical, Strict* (Cobreros et al., 2012), *Measuring inconsistency in knowledge bases* (Grant; Hunter, 2006), *Semi-stable semantics* (Caminada; Carnielli; Dunne, 2012), *Non-deterministic multiple-valued structures* (Avron; Lev, 2005), *The Paraconsistent Logics PJ* (Da Costa; Subrahmanian; Vago, 1991), *Remarks on Annotated Logic* (Da Costa; Abe; Subrahmanian, 1991), *Approaches to Measuring Inconsistent Information* (Hunter; Konieczny, 2005), *Argumentative logics: Reasoning with classically inconsistent information* (Elvang-Goransson; Hunter, 1995), *Transfinite numbers in paraconsistent set theory* (Weber, 2010), *Chunk and permeate, a paraconsistent inference strategy. part I: The infinitesimal calculus* (Brown; Priest, 2004), *Logics with common weak completions* (Galindo et al., 2006), *Algebraic semantics for paraconsistent Nelson's logic* (Odintsov, 2003), *Reasoning with contradictory information using quasi-classical logic* (Hunter, 2000), *An ensemble design of intrusion detection system for handling uncertainty using Neutrosophic Logic Classifier* (Kavitha; Karthikeyan; Sheeba Maybell, 2012), *On distance-based inconsistency reduction algorithms for pairwise comparisons* (Koczkodaj; Szarek, 2010), *On the Ternary Relation and Conditionality* (Beall et al., 2012), *Multiple-conclusion LP and default classicality* (Beall, 2011), *Paraconsistent logics?* (Slater, 1995), *A logic programming system for nonmonotonic reasoning* (Alferes; Damásio; Pereira, 1995).

Table 11. Author Local Impact, Impact measure by H-Index, WoS database.

n.	Author	h_index	g_index	m_index	TC	NP	PY_start
1	Kamide N	8	11	0.5	154	29	2006
2	Arieli O	7	8	0.304	133	8	1999
3	Avron A	7	14	0.304	205	14	1999
4	Da Costa NCA	7	8	0.167	207	8	1980
5	Wansing H	7	9	0.35	153	9	2002
6	Weber Z	7	9	0.583	143	9	2010
7	Hunter A	6	6	0.222	288	6	1995
8	Abe JM	5	11	0.161	124	11	1991
9	Carnielli W	5	7	0.417	60	10	2010
10	Coniglio ME	5	7	0.455	68	14	2011
11	Subrahmanian VS	5	6	0.143	294	6	1987
12	Zamansky A	5	7	0.455	95	7	2011
13	Bueno O	4	4	0.167	68	4	1998
14	Grant J	4	6	0.182	160	6	2000
15	Mendez JM	4	4	0.333	29	9	2010
16	Odintsov SP	4	7	0.211	82	7	2003
17	Omori H	4	7	0.333	68	7	2010
18	Priest G	4	9	0.118	95	9	1988
19	Rivieccio U	4	6	0.4	47	6	2012
20	Robles G	4	4	0.286	31	11	2008

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix.

Table 12. Most Relevant Affiliation on PL (Collection 1), WoS database.

N.	Affiliations	Articles
1	Universidade Estadual de Campinas	51
2	Universidade de São Paulo	22
3	Teikyo University	19
4	Ruhr University Bochum	16
5	Tel Aviv University	16
6	University Maryland	13
7	University Melbourne	12
8	Universidade Paulista	10
9	University Warsaw	10
10	Universidade de Buenos Aires	9
11	University Leon	9
12	University Salamanca	9
13	Linkoping University	8
14	Sobolev Inst Math	8
15	Grad Ctr	7
16	University Birmingham	7
17	University Cagliari	7
18	University Connecticut	7

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix.

The most cited documents in the PL collection (Table 16) were: *Maximal and Premaximal Paraconsistency in the Framework of Three-Valued Semantics* (Arieli; Avron; Zamansky, 2011a), *Algebraic semantics for paraconsistent Nelson's logic* (Odintsov, 2003), *Paraconsistent logic programming* (Blair; Subrahmanian, 1989), *Chunk and permeate, a paraconsistent inference strategy. part I: The infinitesimal calculus* (Brown; Priest, 2004), *Non-deterministic multiple-valued structures* (Avron; Lev, 2005), *Proof theory of Nelson's paraconsistent logic: A uniform perspective* (Kamide; Wansing, 2012), *Reasoning with contradictory information using quasi-classical logic* (Hunter, 2000), *Ideal Paraconsistent Logics* (Arieli; Avron; Zamansky, 2011b), *Classical Negation and Expansions of Belnap–Dunn Logic* (De; Omori, 2015), *Transfinite numbers in paraconsistent set theory* (Weber, 2010), *Revisiting* $\mathbb{Z}$ (Osorio; Carballido; Zepeda, 2014), *Paraconsistent logics?* (Slater, 1995), *Reducing preferential paraconsistent reasoning to classical entailment* (Arieli; Denecker, 2003), *Modeling and reasoning with paraconsistent rough sets* (Vitória;

Małuszyński; Szałas, 2009), *Multiple-conclusion LP and default classicality*(Beall, 2011), Tolerant, Classical, Strict (Cobreros et al., 2012), *An alternative approach for quasi-truth* (Coniglio; Silvestrini, 2014), *Paraconsistency and sette's calculus p1* (Ciuciura, 2015), *Paraconsistent quantum logics* (Chiara; Giuntini, 1989), *Measuring inconsistency in knowledgebases* (Grant; Hunter, 2006).

The Most Local Cited References were: *On the theory of inconsistent formal systems* (Da Costa, 1974), *Logic of Paradox* (Priest, 1979), *A Useful Four-Valued Logic* (Belnap, 1977), *Intuitive semantics for first-degree entailments and 'coupled trees'* (Dunn, 1976), *Constructible falsity and inexact predicates* (Almukdad; Nelson, 1984) (Table 17).

Table 13. Corresponding Author's Country on PL (Collection 1), WoS database.

N.	Country	Articles	Freq	SCP[1]	MCP[2]	MCP_Ratio
1	Brazil	61	0.1377	43	18	0.2951
2	Japan	39	0.08804	29	10	0.2564
3	Usa	36	0.08126	22	14	0.3889
4	United Kingdom	32	0.07223	24	8	0.25
5	Germany	22	0.04966	16	6	0.2727
6	Russia	22	0.04966	19	3	0.1364
7	Poland	21	0.0474	12	9	0.4286
8	Spain	21	0.0474	16	5	0.2381
9	Israel	18	0.04063	12	6	0.3333
10	Italy	17	0.03837	12	5	0.2941
11	Mexico	17	0.03837	16	1	0.0588
12	France	16	0.03612	12	4	0.25
13	Australia	15	0.03386	12	3	0.2
14	Argentina	14	0.0316	11	3	0.2143
15	Belgium	14	0.0316	11	3	0.2143
16	China	13	0.02935	10	3	0.2308
17	Canada	11	0.02483	8	3	0.2727
18	Netherlands	7	0.0158	5	2	0.2857
19	New Zealand	7	0.0158	3	4	0.5714
20	CzechRepublic	5	0.01129	4	1	0.2

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix,
[1]Single Country Publication, [2] Multiple Country Publication.

Table 14. Most Cited Author's Country on PL (Collection 1), WoS database.

N.	Country	TC[1]	AAC[2]	N.	Country	TC	AAC
1	Usa	422	11.72	11	Italy	120	7.06
2	Brazil	342	5.61	12	Argentina	114	8.14
3	United Kingdom	282	8.81	13	France	105	6.56
4	Israel	262	14.56	14	Belgium	95	6.79
5	Japan	206	5.28	15	Luxembourg	89	89.00
6	Spain	190	9.05	16	Mexico	81	4.76
7	Germany	172	7.82	17	Poland	78	3.71
8	Australia	150	10.00	18	New Zealand	67	9.57
9	Russia	131	5.95	19	India	55	13.75
10	Canada	129	11.73	20	Netherlands	50	7.14

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix,
[1] Total Citation, [2]Average Article Citations

Table 15. Most Cited Papers in the WoS database, PL (Collection 1).

N.	Paper	Total Citations	TC per Year
1	Blair; Subrahmanian, 1989	148	4.48
2	Cobreros et al., 2012	113	11.30
3	Grant; Hunter, 2006	107	6.68
4	Caminada; Carnielli; Dunne, 2012	89	8.90
5	Avron; Lev, 2005	88	5.17
6	Da Costa; Subrahmanian; Vago, 1991	65	2.09
7	Da Costa; Abe; Subrahmanian, 1991	55	1.77
8	Hunter; Konieczny, 2005	49	2.72
9	Elvang-Goransson; Hunter, 1995	48	1.77
10	Weber, 2010	44	3.67
11	Brown; Priest, 2004	42	2.33
12	Galindo et al., 2006	42	2.62
13	Odintsov, 2003	40	2.10
14	Hunter, 2000	40	1.81
15	Kavitha; Karthikeyan; Sheeba Maybell, 2012	39	3.90
16	Koczkodaj; Szarek, 2010	39	3.25
17	Beall et al., 2012	38	3.80
18	Beall, 2011	38	3.45
19	Slater, 1995	38	1.40
20	Alferes; Damásio; Pereira, 1995	33	1.22

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix.

Table 16. Most Local Cited Documents on PL (Collection 1), WoS database.

N.	Document	Year	L[1]	GC[2]	LC/GC Ratio (%)
1	Arieli; Avron; Zamansky, 2011a	2011	22	33	66.67
2	Odintsov, 2003	2003	17	40	42.50
3	Blair; Subrahmanian, 1989	1989	16	148	10.81
4	Brown; Priest, 2004	2004	13	42	30.95
5	Avron; Lev, 2005	2005	13	88	14.77
6	Kamide; Wansing, 2012	2012	13	31	41.94
7	Hunter, 2000	2000	11	40	27.50
8	ArielI; Avron; ZamanskY, 2011b	2011	11	21	52.38
9	De; Omori, 2015	2015	10	24	41.67
10	Weber, 2010	2010	9	44	20.45
11	Osorio; Carballido; Zepeda, 2014	2014	9	9	100.00
12	Slater, 1995	1995	8	38	21.05
13	Arieli; Denecker, 2003	2003	8	28	28.57
14	Vitória; Małuszyński; Szałas, 2009	2009	8	29	27.59
15	Beall, 2011	2011	8	38	21.05
16	Cobreros et al., 2012	2012	8	113	7.08
17	Coniglio; Silvestrini, 2014	2014	8	22	36.36
18	Ciuciura, 2015	2015	8	8	100.00
19	Chiara; Giuntini, 1989	1989	7	31	22.58
20	Grant; Hunter, 2006	2006	7	107	6.54

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix,
[1]Local Citation, [2]Global Citation.

Table 17. Most Local Cited References on PL (Collection 1), WoS database.

N.	Cited References	Citations
1	Da Costa, 1974	86
2	Priest, 1979	78
3	Belnap, 1977	74
4	Dunn, 1976	50
5	Almukdad; Nelson, 1984	47
6	Carnielli W., 2007	45
7	Nelson D., 1949	44
8	Carnielli Wa	43
9	Priest G., 2002	36
10	Arieli O, 1998	35
11	Arieli O., 1996	34
12	Ryle, 1977	32
13	Anderson A. R., 1975	31
14	Priest Graham, 2006	30
15	Gurevich Y., 1977	26
16	Jaskowski S., 1969	26
17	Vorob'evNn, 1952	25
18	Sette A. M., 1973	24
19	Avron A, 1991	23
20	Arieli O, 2011	22

Source: Elaborated by the authors from data generated by biblioshiny for bibliometrix.

3.2 The scientific production related to Paraconsistent Annotated Logic

The selected 20 articles on PAL were analyzed according to the extracted data from the following fields: *AU-Authors*, *TI-Document Title*, *DE-Author Keywords*, *ID-Keywords Plus®*, *AB-Abstract*, *PY-Year Published* (Table 18). The results were classified by the contributions of the articles to the research areas listened in the WoS database. A total of 37 categories were identified, which highlight the varied application of PAL: Computer Science 8, Engineering 8, Chemistry 3, Science Technology Other Topics 3, Automation Control Systems 2, Environmental Sciences Ecology 2, Education Educational Research 1, Instruments Instrumentation 1, Materials Science 1, Mathematical Computational Biology 1, Mathematics 1, Medical Informatics 1, Physics 1, Public Environmental Occupational Health 1, Spectroscopy 1, Telecommunications 1, Transplantation 1.

3.2 The scientific production related to Paraconsistent Annotated Logic models

The five articles identified as related to PAL-based models were: Bonilla et al., 2019, De Carvalho et al., 2021, Mario et al., 2010, Langa et al., 2021, Carbogim; Corrêa Da Silva, 1998. None of them addressed PAL models that evaluate the intellectual property as a product to be commercialized (Table 19).

4. Conclusion

The systematic literature review on Paraconsistent Logic conducted in this research, based on papers indexed in the Web of Science up to November of 2021, resulted in a total of 894 documents and a collection of 460 articles written in English and published in peer-reviewed journals. Within the Pl collection were found 20 articles related to Paraconsistent Annotated Logic which englobed 37 different research areas: Engineering, Computer Science, Automation Control Systems, Chemistry, Environmental Sciences Ecology, Education Educational Research, Instruments Instrumentation1, Materials Science1, Mathematical Computational Biology, Mathematics, Medical Informatics, Public Environmental Occupational Health, Telecommunications.

Five of the PAL-related articles were identified as dealing with the application of PAL to the improvement of decision-making models for specialized systems and artificial intelligence. However, none of the analyzed models is associated with Academic Entrepreneurship development. In this sense, from this review was possible to pinpoint evidence of research opportunity to develop models that aim to evaluate the generated intellectual property as a product to be commercialized, particularly in the studies by Fabio Romeu de Carvalho, João Inácio da Silva Filho, and Jair Minoru Abe.

Table 18. Articles on PAL retrieved from WoS database (Collection 2).

Reference	Title
Nakamatsu; Mita; Shibata, 2007	An intelligent action control system based on extended vector annotated logic program and its hardware implementation
Coelho et al., 2019	Hybrid pi controller constructed with paraconsistent annotated logic
Da Silva Filho et al., 2021	Paraconsistent annotated logic algorithms applied in management and control of communication network routes
Bellinello et al., 2020	Pal-vmea: a novel method for enhancing decision-making consistency in maintenance management
Garcia et al., 2019	Analysis of raman spectroscopy data with algorithms based on paraconsistent logic for characterization of skin cancer lesions
Carbogim; Corrêa Da Silva, 1998	Annotated logic applications for imperfect information
Mu et al., 2006	Handling non-canonical software requirements based on annotated predicate calculus
Da Silva Filho et al., 2016	Support at decision in electrical systems of subtransmission through selection of topologies by a paraconsistent simulator
Carvalho et al., 2018	A study of paraconsistent artificial neural cell of learning applied as pal2v filter
Oshiyama et al., 2012	Medical equipment classification: method and decision-making support based on paraconsistent annotated logic
De Carvalho et al., 2021	Rotary inverted pendulum identification for control by paraconsistent neural network
Lu, 1996	Logic programming with signs and annotations
Lambert-Torres et al., 2017	Some practical approaches to a course on paraconsistent logic for engineers
Mario et al., 2010	Paraconsistent artificial neural network as auxiliary in cephalometric diagnosis
Bonilla et al., 2019	Contribution of the paraconsistent tri-annotated logic to emergy accounting and decision making
Giannetti et al., 2009	The reliability of experts' opinions in constructing a composite environmental index: the case of esi 2005
Da Costa; Abe; Subrahmanian, 1991; Langa et al., 2021	Remarks on annotated logic
Campolina et al., 2017	Multi-criteria decision analysis for health technology resource allocation and assessment: so far and so near?
Langa et al., 2021	How the global initiative report's indicators are related to the strong sustainability concept? - a paraconsistent approach
Dos Santos et al., 2016	Paraconsistents artificial neural networks applied to the study of mutational patterns of the f subtype of the viral strains of HIV-1 to antiretroviral therapy

Source: Elaborated by the authors (2022).

Table 19. The main objective of articles on PAL-based models (Collection 3), WoS database.

Reference	Objective
Bonilla, Silvia H.; Papalardo, Fabio;Tassinari, Celso A.; Sacomano, Jose B.; De Carvalho, Fabio Romeu (2019)	Propose a comprehensive tool to support decision-making in accounting emerged with an application model of Paraconsistent Tri-Annotated Logic (PL3v) to compare different systems and allow the selection of these alternatives with the best performance from the point of view of sustainability defined in terms of energy.
Carbogim; Corrêa Da Silva (1998)	To verify and confirm the importance of annotated logics as a tool for developing knowledge-based and automated reasoning systems in Artificial Intelligence
De Carvalho, Arnaldo; Justo, Joao Francisco; Angelico, Bruno Augusto; De Oliveira, Alexandre Manicoba; Da Silva Filho, Joao Inacio (2021)	Describe a novel activation function reasoned on the paraconsistent annotated logic by two-value annotations (PAL2v) rules, a variation of PL, allowing the design of a new paraconsistent neural net (PNN), applied in model identification for control (I4C) of a closed-loop rotary inverted pendulum (RIP) system.
Langa, Estevao S.; Agostinho, Feni;Liu, Genguyan; Giannetti, Biagio F.; Almeida, Cecilia M. V. B (2021)	Apply the paraconsistent annotated evidential logic (PAEL) on opinions of experts in the sustainability theme to verify whether the *Global Reporting Initiative* (GRI) indicators are aligned to the concept of 'strong' sustainability.
Mario, Mauricio C.; Abe, Jair M.; Ortega, Neli R. S.; Del Santo, Marinho Jr (2010)	Present an application of the paraconsistent artificial neural network (PANN) in the analysis of cephalometric variables and to provide an orthodontic diagnosis.

Source: Elaborated by the authors (2022).

Acknowledgments

The authors acknowledge financial assistance from the Brazilian research funding agencies as CAPES (Coordination for the Improvement of Higher Education Personnel) under Finance Code 001, a Brazilian foundation within the Ministry of Education (MEC), CNPq (National Council for Scientific and Technological Development), a Brazilian foundation associated to the Ministry of Science, Technology and Innovations (MCTI), and FAPITEC/SE (the Foundation of Support to Research and Technological Innovation of the State of Sergipe).

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