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SCIENTIFIC PRODUCTIVITY OF DOCTORS IN REGIONAL DEVELOPMENT IN BRAZIL: PATTERNS AND CHALLENGES FROM A BIBLIOMETRIC PERSPECTIVE[1]

PRODUTIVIDADE CIENTÍFICA DE DOUTORES EM DESENVOLVIMENTO REGIONAL NO BRASIL: PADRÕES E DESAFIOS EM PERSPECTIVA BIBLIOMÉTRICA

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ABSTRACT

This study analyzes the scientific productivity of PhDs graduated from Postgraduate Programs in Regional Development in Brazil. A total of 271 theses defended between 2005 and 2020 were analyzed, resulting in the identification of 1,765 full articles published in journals indexed in Qualis/CAPES. The research used bibliometric techniques and the application of Lotka's Law, with adjustment by the generalized inverse power model and least squares estimation, to assess the distribution pattern of the scientific production of graduates. The results indicate that the productivity of PhDs does not follow the classic pattern predicted by Lotka's Law, presenting a more balanced distribution, with less concentration of production in a few authors and greater collective participation in the authorship of articles. This pattern reflects the interdisciplinary nature of the field and the stage of consolidation of Regional Development Programs in Brazil. The study offers relevant support for improving institutional evaluation policies, encouraging qualified publication, and internationalization in the area.

Keywords: Regional Development; Scientific Productivity; Bibliometrics; Lotka's Law; Doctors.

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RESUMO

Este estudo analisa a produtividade científica dos doutores titulados nos Programas de Pós-Graduação em Desenvolvimento Regional no Brasil. Foram analisadas 271 teses defendidas entre 2005 e 2020, resultando na identificação de 1.765 artigos completos publicados em periódicos indexados no Qualis/CAPES. A pesquisa empregou técnicas bibliométricas e a aplicação da Lei de Lotka, com ajuste pelo modelo do poder inverso generalizado e estimativa por mínimos quadrados, para avaliar o padrão de distribuição da produção científica dos egressos. Os resultados indicam que a produtividade dos doutores não segue o padrão clássico previsto pela Lei de Lotka, apresentando uma distribuição mais equilibrada, com menor concentração de produção em poucos autores e maior participação coletiva na autoria dos artigos. Esse padrão reflete a natureza interdisciplinar do campo e o estágio de consolidação dos Programas de Desenvolvimento Regional no Brasil. O estudo oferece subsídios relevantes para o aprimoramento das políticas institucionais de avaliação, incentivo à publicação qualificada e internacionalização na área.

Palavras-chave: Desenvolvimento Regional; Produtividade Científica; Bibliometria; Lei de Lotka; Doutores.

INTRODUCTION

Doctors in Regional Development occupy a central position in structuring, recognizing and advancing this field of study, whose interdisciplinary nature inserts it into the debate on territorial planning, public policies and regional sustainability. The scientific productivity of these professionals not only reflects the strength of the field, but also directly influences it, constituting a relevant indicator of its consolidation

Since the creation of CAPES in 1951, stricto sensu postgraduate studies in Brazil have been one of the main instruments for training qualified human resources. From only 67,820 students in 1996, it grew to 292,766 in 2019, of which 118,122 were doctoral program students (CAPES, 2021). Within this expansion, the area of Urban and Regional Planning/Demography, in particular the subfield of Regional Development, has gained prominence. Theis (2019) points out that, from just two programs in 1970, the subfield grew to eighteen academic programs in 2017.

The first stricto sensu program in Regional Development was created at the University of Santa Cruz do Sul (UNISC), with a master's degree in 1994 and a doctorate in 2002. Since then, the number of programs and PhDs awarded has grown considerably, totaling two hundred and seventy-

one PHDs between 2005 and 2020. As observed by Lima da Silveira et al. (2020), it is expected that these graduates make a significant contribution to scientific production in the field.

Scientific productivity is usually measured by the publication of articles in indexed journals. To analyze the distribution of this productivity, this study uses Lotka's Law as a methodological tool. Proposed in 1926, Lotka's Law describes that a few authors are responsible for the majority of scientific publications, while most of the authors contribute just one article. After Lotka's seminal work, international studies (Ahmad; Batcha; Jahina, 2019; Tunga, 2020; Ahmad; Batcha, 2020; Kushairi; Ahmi, 2021, among others) and national studies (Alvarado, 2006; Sobrino; Caldes; Guerrero, 2008; Ubstegui, 2009; Parizoto *et al*., 2012; Voese; Mello, 2013; Andrade *et al*.,2014; Perlin *et. al*., 2017; Mello *et. al*., 2017; Da Silva *et al*., 2019; Fernandes *et. al*., 2020, among others) have focused on monitoring and analyzing scientific productivity in different fields of knowledge, in order to identify relevant points in its dynamics.

However, there are no studies that have applied this approach to the group of PhDs in Regional Development. Therefore, this article aims to fill this gap by analyzing these doctors' productivity and checking whether it follows the pattern described by Lotka's Law. The article is structured in five sections: introduction, theoretical framework, methodology, results and discussion, and concluding remarks.

Unlike other studies, this one uses the generalized inverse power model and least squares estimation, seeking greater precision in the analysis. The assumption is that the consolidation of the field of Regional Development is directly linked to the commitment of its doctors to the production and dissemination of scientific knowledge.

THEORETICAL FRAMEWORK

In 1926, Alfred Lotka examined the productivity patterns of authors in the fields of chemistry and physics, providing the initial foundations for bibliometrics through what became, in his honor, known as Lotka's Law. This law deals with the frequency of publication of authors in a given field of knowledge. According to Lotka, some researchers, supposedly of greater prestige in their fields, produce many works; while the many with less prestige, publish little (Voos, 1974).

The generalized form of the law can be expressed as: $Y = C \cdot x^{-n}$, where Y represents the number of authors with x publications, and the parameters n (exponent) and C (constant) are estimated based on a set of data on author productivity. The Law states that the number of authors who contribute n times is approximately $1/n^2$ of those who contribute only once, with around 60% of authors producing only one work (Potter, 1988; Hertzel, 2010).

According to Guedes and Borschiver (2005), the applicability of Lotka's Law can be seen in the researchers' productivity assessment, in the identification of more consolidated research centers and in recognizing the solidity of a given scientific area. The more mature a field is, the higher the proportion of authors who produce multiple articles in a period tends to be.

Over the years, Lotka's Law has aroused the interest of Brazilian researchers. Alvarado (2006), for instance, analyzed the distribution of generalized inverse power by using the linear least squares method. Applying this model to the Nursing literature, he concluded that the field fitted well with Lotka's Law, with parameters n = 2.78 and C = 0.7986, at a significance level of 0.01.

Sobrino, Caldes and Guerrero (2008) applied the Law to a set of authors with publications in the field of Information Science between 1996 and 2007. The results indicated that n = 2.75 and that 79% of the researchers had only published one paper - an excellent fit to Lotka's model, although lower than that obtained in the studies by Voos (1974) and Sen, Taib and Hassan (1996), also in this field.

Urbizagastegui (2009) investigated the growth of literature on Lotka's Law from 1922 to 2003. He identified three hundred and eighty-one articles, 60% of which were published after 1980. According to the author, the growth of the literature follows an exponential model, with an average rate of 7.5% per year and a doubling time each 9.6 years. The number of authors has also increased, at a rate of 7.3% per year and has doubled every 10 years.

Parizoto et al. (2012) analyzed dissertations and theses on breastfeeding written between 1999 and 2010 in Nursing PPGs in Brazil. When comparing the group of 12 supervisors who supervised fifty dissertations/theses with another group of 46 supervisors who supervised 46 papers, the authors confirmed that the data corroborated Lotka's Law in the area studied.

Voese and Mello (2013) applied Lotka's Law to an analysis of two hundred and eighty-seven articles presented at the Brazilian Cost Congress, on the topic of Strategic Cost Management (1994-2011). They found that 84.53% of the authors had produced just one paper, confirming the low productivity and adjustment to the Law, with C = 3.14.

Andrade et al. (2014) carried out a bibliometric analysis on Strategic Maps (1987-2013), with sixty-one articles from the CAPES and ProQuest databases. Their results showed that 90.7% of the authors had only one publication, again confirming the validity of Lotka's Law.

Mello et al. (2017) mapped scientific production in Auditing, based on one hundred and forty-five articles published between 1989 and 2013 in twenty-six Brazilian accounting journals. The data revealed that 81.2% of the authors published only once, showing the presence of Lotka's Law in the area.

Bartz, Turcato and Baggio (2019) applied Lotka, Bradford and Zipf's Laws to publications on collaborative governance (2009-2018) on the Web of Science database. They found that 62.82% of authors had only one publication.

Fernandes et al. (2020) analyzed the academic performance of biodiesel research, based on theses and dissertations published between 2005 and 2019. They evaluated the productivity of the supervisors through Lotka's Law, using the generalized inverse power model via least squares. They found that the two hundred works were supervised by seventy-seven professors, whose distribution fitted the model.

Lotka's Law has been widely used as a tool to measure scientific productivity in different areas of knowledge, making it possible to identify patterns of production concentration and the maturity of specific scientific fields. Studies such as those by Alvarado (2006) in Nursing, Sobrino, Caldes and Guerrero (2008) in Information Science, and Mello et al. (2017) in Auditing have shown that, in contexts with strong scientific institutionalization, the distribution of production follows Lotka's model: a high proportion of authors who publish only once. These studies reinforce the applicability of the Law as a criterion for assessing the productive density and consolidation of scientific communities. At the same time, studies such as Urbizagastegui's (2009) show the continued growth in the use of bibliometrics, demonstrating its maturity as a field of analysis.

By using the inverse power model generalized by least squares, these authors' contribution becomes significant, as they offer replicable methods for testing the adherence of scientific productivity to Lotka's Law. This approach was adopted by Fernandes et al. (2020) and Bartz, Turcato and Baggio (2019), among others, who investigated topics such as biodiesel and collaborative governance. The methodological consistency between these studies indicates that the Law can be a valid instrument for evaluating the productive structure of emerging and multidisciplinary areas, as long as it takes into account its limitations and the epistemological context of the area evaluated. In addition, these studies make it possible to create productivity rankings and help identify nuclei of academic excellence, the most productive supervisors and possible asymmetries when it comes to training new researchers.

In the field of Regional Development, the applicability of Lotka's Law becomes even more relevant, considering its interdisciplinary nature and its level of academic consolidation. The study by Dill, Allebrandt and Brum (2023) reveals a more equitable distribution of scientific production. This evidence suggests that, in the context of Regional Development, the logic of scientific production is less centered on highly productive authors and more distributed among researchers, which may reflect a more intense collaboration dynamic and a greater diversity of research agendas.

Using Lotka's Law as an analytical tool makes it possible not only to compare the field of Regional Development with other areas of knowledge, but also to understand its specificities and enhance academic strengthening strategies - such as policies to encourage publication, collaborative networks and the formation of inter-institutional research groups.

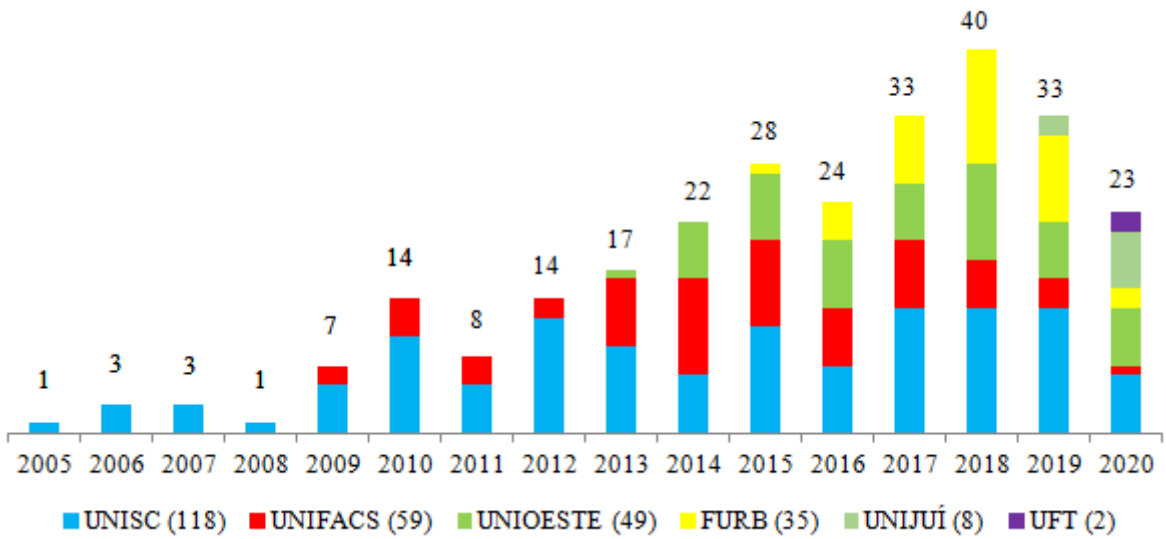
RESEARCH METHOD

Data was collected and analyzed between January and March of 2021, through documentary research. This is justified because it allows for the selection, organization, treatment and interpretation of information that was crude and dispersed. We searched for theses in Regional Development listed on the Sucupira Platform between 2000 and 2019. The 2020 theses, which were not available on the platform, were located directly on the websites of the stricto sensu Graduate Programs in Regional Development. The decision to search for data on the websites was intended to expand the database, rather than the other way around.

To select the PPGs, CAPES' portal was consulted in order to identify the Higher Education Institutions (HEIs) that have recommended and recognized doctoral courses linked to the broad area of Urban and Regional Planning/Demography, sub-area Urban and Regional Planning. Nineteen PPGs were found. However, those that did not have the term "Regional Development" in their name were excluded, leaving eight PPGs linked to the following HEIs: Fundação Universidade Federal do Tocantins (UFT), Universidade de Santa Cruz do Sul (UNISC), Universidade do Contestado (UNC), Universidade Estadual do Oeste do Paraná (UNIOESTE), Universidade Regional de Blumenau (FURB), Universidade Regional do Noroeste do Estado do Rio Grande do Sul (UNIJUÍ), Universidade de Salvador (UNIFACS), and Universidade Tecnológica Federal do Paraná (UTFPR).

On both Sucupira Platform and the PPG websites, it was not possible to locate theses defended at UNC and UTFPR, possibly due to the recent start of their doctoral classes in 2021 and 2018, respectively. Thus, two hundred and seventy-one theses were identified in six PPGs, as shown in Figure 1.

Figure 1 | Defended theses



Source: Research data.

To collect information on scientific productivity, a nominal search was carried out on the Lattes Platform for the authors of two hundred and seventy-one theses identified. Nine of these authors did not have their CVs registered, which generated data on two hundred and sixty-two doctors; two hundred and one of them had updated their CVs less than twelve months beforehand.

The CVs were saved in eXtensible Markup Language format and exported to Coletaprod® in order to extract information such as the researcher's name, the title of the article, the format (full or abstract), the year of publication, the name of the journal, ISSN, date of entry and completion of the doctoral course. The data was then exported and tabulated in a spreadsheet. Coletaprod® is an open source software developed and used by the Federal University of São Paulo to monitor scientific production and extract data from the institution's teaching staff.

According to the data extracted and presented in Table 1, the set of publications by major area of knowledge highlights Applied Social Sciences with 34.74% of the total, followed by Human Sciences with 12.05% and Health Sciences with 4.53%. Although 46.14% of the papers do not state the major field, it can be seen that the majority of publications are concentrated in Applied Social Sciences - which was expected, considering that the Postgraduate Programs in Regional Development are inserted in this major field of knowledge.

Table 1 | Scientific production by major area of knowledge

	Works at events		Articles published in journals		Book chapters		Books published or organized		TOTAL	
	n	%	n	%	n	%	n	%	n	%
Applied Social Sciences	2.003	32,02	1.174	38,96	535	36,90	212	36,87	3.924	34,74
Human Sciences	630	10,07	373	12,38	232	16,00	126	21,91	1.361	12,05
Health Sciences	363	5,80	104	3,45	33	2,28	12	2,09	512	4,53
Engineering	102	1,63	27	0,90	25	1,72	11	1,91	165	1,46
Agricultural Sciences	29	0,46	16	0,53	8	0,55	2	0,35	55	0,49
Exact and Earth Sciences	24	0,38	8	0,27	1	0,07	5	0,87	38	0,34
Biological Sciences	15	0,25	7	0,23	2	0,14	4	0,70	28	0,25
Not informed	3.090	49,39	1.304	43,28	614	42,34	203	35,30	5.211	46,14
TOTAL	6.256	100,00	3.013	100,00	1.450	100,00	575	100,00	11.294	100,00

Source: Research data.

Preliminarily, three thousand thirteen articles published in scientific journals were identified in the Lattes CVs. However, only complete articles were considered; they were indexed in the 2013-2016 Qualis/CAPES quadrennium (strata A, B and C) and published after entering the doctoral program. The criterion used was that the journals that are truly important in the academic environment were evaluated by the so-called "Qualis Periodicals", and that the insertion of new researchers into the academic environment occurs, in most cases, after they start the doctorate program.

According to Urbizagastegui (2002), there are three possible ways of counting authors and articles when using Lotka's Law: 1) direct counting, in which only the main authors are considered; 2) complete counting, in which the main author and the secondary author(s) are considered; and 3) adjusted counting, in which a fraction is assigned to each author according to the number of participants in the work. According to the author, the first and last forms do not make much difference but either the first or the second one are commonly used. In this study, we opted for the complete counting because it reflects contemporary production behavior more accurately, as highlighted by Cândido et al. (2018).

Thus, we counted one thousand seven hundred and sixty-five articles authored and co-authored by two hundred and nineteen PhDs who graduated from the Regional Development PPGs between 2005 and 2020. In this universe, it is interesting to note that 19.18% (n = 52) of the doctors did not publish articles in journals indexed in Qualis/CAPES in the 2013-2016 quadrennium, after entering their respective doctoral courses.

Scientific productivity was calculated using the model known as inverse power, generalized by the least squares method, and followed the routine proposed by Alvarado (2006) - in order to test the hypothesis of whether or not the data fit Lotka's Law, as described below:

$$Fe = C\frac{1}{x^n} \quad (1)$$

Where,

Fe = is the expected probability that the researcher will make x publications;

C & n = are two parameters to be estimated from the observed data.

Parameter C represents the theoretical percentage of authors who contributed only one paper in the distribution of productivity over the period studied. It is calculated according to equation (2):

$$C = \frac{1}{\sum_{X=1}^{P-1} \frac{1}{x^n} + \frac{1}{(n-1)Pn-1} + \frac{1}{2^{pn}} + \frac{n}{24(P-1)^{n+1}}} \quad (2)$$

Where,

x = is the number of contributions per author;

n = is the value calculated in equation (3);

P = is the number of pairs observed.

The parameter n, relating to the slope of Lotka's Law, is calculated by linear least squares using equation (3) below:

$$n = \frac{N\sum XY - \sum X \sum Y}{N\sum X^2 - (\sum X)^2} \quad (3)$$

Where,

N = is the number of data pairs;

X = log x (base 10);

Y = log y (base 10).

The Kolmogorov-Smirnov (K-S) test is applied and it is checked whether the critical value for acceptance, at a significance level of α = 0.01 (obtained using the formula 1.63/√n) when compared to the maximum difference, indicates the rejection or acceptance of the research hypothesis. In other words, it assesses whether or not the scientific productivity of PhDs in Regional Development fits Lotka's Law.

RESULTS PRESENTATION AND DISCUSSION

The results from the descriptive analysis of data are presented and discussed below, fundamentally related to the number of publications, authors and journals, as well as the results from the application of Lotka's Law - calculated using the inverse power model generalized by the least squares method.

DESCRIPTIVE DATA ANALYSIS

Based on the assumption that stricto sensu PPGs, at doctoral level, train researchers, the analysis of scientific production in relation to the authors and co-authors of papers published in indexed scientific journals identified one thousand seven hundred and sixty-five articles; of which, 46.28% as authors and 53.72% as co-authors named PhDs in Regional Development.

Extending the analysis to the number of authors per article, an average of 3.38 researchers per article was calculated. This figure exceeds those of international studies by Ahmad, Batcha and Jahina (2019), on artificial intelligence, and Tunga (2021) on horticulture, whose averages were 3.31, 2.52 and 2.48, respectively. In relation to national studies, the average was lower than the work by Urbizagastegui (2009), which indicated an average of 4.65 in articles referring to the growth of literature on Lotka's Law. However, the average was higher than studies by Voese and Mello (2013) on strategic cost management, and Cândido et al. (2018) on finance literature, with averages of 1.93 and 1.43, respectively.

Analyzing the evolution of research over time is an important factor in evaluating scientific production and communication activities. It demonstrates the strengthening or increase in interest in a given field of knowledge. In this sense, Table 2 below shows the temporal evolution, whose growth coincides with the increase in the number of doctors graduated, as shown in Figure 1. Apparently, the growth in the number of courses offered and the number of people entering and graduating has impacted the increase in published articles, demonstrating quantitative and qualitative growth in the field.

Table 2 | Time evolution

Year Qualis*	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	TOTAL
A1					1			1		2		8	3	10	9	8	9	4	6	**61**
Spanish																	1			**1**
English												1	1	5	3	2	3	1	1	**17**
Portuguese					1			1		2		7	2	5	6	6	5	3	5	**43**
A2					1	2	1		4	4	1	5	8	5	13	13	21	18	15	**111**
Spanish									1								1		2	**4**
English										1			4	2	3	1	3	3	5	**22**
Portuguese					1	2	1		3	3	1	5	4	3	10	12	17	15	8	**85**
B1	2	3	3	2	3	3	1	3	2	8	19	22	20	46	52	73	53	31	40	**386**
Spanish			1					1			1				3	1			1	**8**
English													1	4	1	3	1		1	**11**
Portuguese	2	3	2	2	3	3	1	2	2	8	18	22	19	42	48	69	52	31	38	**367**
B2	1	5	2	4		6	4	8	6	13	18	30	30	45	42	52	41	40	78	**425**
Spanish		1							1				1				1			**4**
English																1		1	2	**4**
Portuguese	1	4	2	4		6	4	8	5	13	18	30	29	45	42	51	40	39	76	**417**
B3			1	1	3	3	2	3	2	9	14	14	38	37	56	39	27	27	33	**309**
Spanish									1								1			**2**
English															3	1	2	1		**7**
Portuguese			1	1	3	3	2	3	1	9	14	14	38	37	53	38	24	26	33	**300**
B4	2	1	1	1	1	6	1	3	6	6	13	20	28	42	38	47	39	28	23	**306**
Spanish															1				1	**2**
English														1				1	1	**3**
Portuguese	2	1	1	1	1	6	1	3	6	6	13	20	28	41	37	47	39	27	21	**301**
B5								1	1	4	2	17	9	13	10	12	17	28	24	**138**
English												1								**1**
Portuguese								1	1	4	2	16	9	13	10	12	17	28	24	**137**
C				2	1	1		1	1			5	1	3	2	5	2	2	3	**29**
Portuguese				2	1	1		1	1			5	1	3	2	5	2	2	3	**29**
TOTAL	5	9	7	10	10	21	9	20	22	46	67	121	137	201	222	249	209	178	222	1.765

* Among the evaluation areas in which the journal was classified, the highest classification was considered

Source: Research data.

Bearing in mind the notion that scientific knowledge only acquires value once it is disseminated to the scientific community, it is clear that researchers are concerned with publishing the results of their studies, in order to validate them as scientific knowledge in renowned journals. Although there are controversies, Frigeri and Monteiro (2014) argue that the Qualis/CAPES scientific journal classification system is a set of procedures used to differentiate scientific production; among its purposes, it seeks to indicate the most relevant vehicles for each area of knowledge, both for researchers and for research funding agencies.

Qualis/CAPES stratification classified journals as A1, A2, B1, B2, B3, B4, B5 and C in its latest indexing, in the 2013-2016 quadrennium, with stratum A1 having the highest weight and stratum C having the lowest weight (zero weight). In this context, the table above shows that articles in strata B2 (n = 425), B1 (n = 386), B3 (n = 309), B4 (n = 306) and B5 (n = 138) are predominant, accounting for 88.61% of publications, with percentages of 24.08%, 21.87%, 17.51%, 17.34% and 7.82%, respectively. Articles in stratum A appear in second place, with A2 (n = 111) and A1 (n = 61) accounting for 9.75% of the total. Finally, stratum C has twenty-nine articles, or 1.64% of the publications.

In addition to the stratum in which an article was published, it is also pertinent to look at the language in which it reached its readership. Guimarães and Machado-da-Silva (2004) note that the main reason for publishing in English is the growing need to bring scientific work to a wider audience, which inevitably means targeting countries where Portuguese is not the dominant language. Based on this, it is assumed that the use of the Spanish language, and especially the English language is one of the requirements for the internationalization of the knowledge produced by doctors in Regional Development.

In this respect, the table above shows the almost absolute predominance of the Portuguese language, with 95.12% (n = 1,679) of the publications, followed by the English language, with 3.69% (n = 65), and finally the Spanish language, with 1.19% (n = 21). It is important to note that 66.67% of the articles in Spanish and 86.15% in English were published in the last five years, demonstrating the recent concern of researchers to publish not only in Portuguese, in order to internationalize their findings and/or to meet the requirements of specific journals. However, it seems that the group of doctors in Regional Development still has a long way to go as far as internationalization is concerned.

Table 3 identifies six hundred and eight journals in which PHDs in Regional Development are published, in print or online, in scientific journals that publish full articles. Twenty-one of these journals were responsible for publishing the intellectual output of five hundred and thirty-three articles, indicating a concentration of journals, where 3.45% of the journals published 30.20% of the articles.

Table 3 | Most common journals

Journal title	n	%	% Accumulated
Revista do Desenvolvimento Regional (REDES)	50	2,83	2,83
Desenvolvimento em Questão	44	2,49	5,33
Revista de Desenvolvimento Econômico (RDE)	44	2,49	7,82
Espacios (Caracas)	43	2,44	10,25
Desenvolvimento Regional em Debate	39	2,21	12,46
Revista Brasileira de Desenvolvimento Regional	37	2,10	14,56
Acadêmico Mundo	27	1,53	16,09
Research, Society and Development	27	1,53	17,62
Rio do sul	26	1,47	19,09
Contribuciones a las Ciencias Sociales	21	1,19	20,28
Revista Grifos	21	1,19	21,47
Revista Interdisciplinar de Promoção da Saúde	19	1,08	22,55
Fólio (Centro Universitário Metodista)	19	1,08	23,63
Colóquio (Taquara)	19	1,08	24,70
Observatorio de la Economía Latinoamericana	18	1,02	25,72
Revista de Administração de Empresas Eletrônica	16	0,91	26,63
Ágora (UNISC)	15	0,85	27,48
Diálogos & Ciência	15	0,85	28,33
Ciências Sociais em Perspectiva	12	0,68	29,01
Atitude (Porto Alegre)	11	0,62	29,63
Revista de Gestão e Organizações Cooperativas	10	0,57	30,20
Outros (587)	1.232	69,80	100,00
TOTAL	1.765	100,00	

Source: Research data.

In his study, Theis (2019) listed twelve journals specifically focused on regional development. Out of these, Table 3 shows that five rank among the top six. Of particular note is *REDES - Revista do Desenvolvimento Regional* (Journal of Regional Development) linked to the PPG in Regional Development at UNISC with fifty publications; followed by *Desenvolvimento em Questão* (Development at Stake) linked to the PPG in Regional Development at UNIJUÍ; and *RDE - Revista de Desenvolvimento Econômico* (Journal of Economic Development), linked to the PPG in Regional and Urban Development at UNIFACS, both with forty-four publications. Lastly, the journals *Desenvolvimento Regional em Debate* (Regional Development in Debate) linked to the PPG in Regional Development at UNC, and *Revista Brasileira de Desenvolvimento Regional* (Brazilian Journal of Regional Development) linked to the PPG in Regional Development at FURB, with thirty-nine and thirty-seven publications, respectively.

With regard to productivity, it is worth remembering that the concept used here is defined by the number of articles published, a definition commonly used in bibliometric research. Table 4 shows the most productive PHDs, of which 8.21% (n = 18) were responsible for publishing 33.65% (n = 594) of the articles. The following stand out: Nilton Marques de Oliveira, Hildegard Hedwig Pohl, Valdir Roque Dallabrida, Sérgio Luís Allebrandt, David Lorenzi Junior, Moacir Piffer, Luciana Scherer and Luciana Virgínia Mario Bernardo, responsible for the publication of 19.60% of the total number of articles.

These data refer to the method of this study, Lotka's Law, according to which some researchers, supposedly of greater prestige in the field of Regional Development, produce a lot, while many researchers of lesser prestige produce little.

Table 4 | Most productive researchers

Researcher (Year of entry into doctoral program)	Qualis*								TOTAL	%	% Accumulated
	A1	A2	B1	B2	B3	B4	B5	C			
Nilton Marques de Oliveira (2012)		4	15	14	21	11	1		66	3,74	3,74
Hildegard Hedwig Pohl (2002)		6	7	26	11	8	1		59	3,34	7,08
Valdir Roque Dallabrida (2002)	3	7	11	10	11	2		1	45	2,55	9,63
Sérgio Luís Allebrandt (2005)		3	20	7	5	3	2		40	2,27	11,90
David Lorenzi Junior (2010)			8	9	10	11			38	2,15	14,05
Moacir Piffer (2005)	1	2	6	10	7	5	1	3	35	1,98	16,03
Luciana Scherer (2016)			17	3	7	3	4	1	35	1,98	18,02
Luciana V. Mario Bernardo (2016)	2	1	15	5	3	2			28	1,59	19,60
Gleimiria Batista da C. Matos (2009)		6	12		4	3	3		28	1,59	21,19
Sandra Mara Stocker Lago (2010)		2	2	10	8	1	4		27	1,53	22,72
José Elmar Feger (2006)	1	2	6	9	8	1			27	1,53	24,25
Jerisnaldo Matos Lopes (2013)				1	18	4	2		25	1,42	25,67
Roberto Tadeu R. Morais (2009)			1	8	2	14			25	1,42	27,08
Udo Strassburg (2012)		1	3	5	7	8	1		25	1,42	28,50
Bárbara Françoise Bauermann (2012)	4	2	2	7	6	2			23	1,30	29,80
Valdinho Pellin (2012)			10	4	3	4	2		23	1,30	31,10
Cátia Dagnoni (2013)							23		23	1,30	32,41
Marcos Paulo Dhein Griebeler (2009)			2	5	5	10			22	1,25	33,65
Others	50	75	249	292	173	214	94	24	1.171	66,35	100,00
TOTAL	61	111	386	425	309	306	138	29	1.765	100,00	

* It was considered the highest rating among the evaluation areas in which the journal was classified.

Source: Research data.

It is important to note that some of the researchers named above belong to the teaching staff of stricto sensu PPGs and, in these cases, the amount of advisees the teacher has is the reason behind this. Thus, those with more advisees will generally have more articles with their name as author or co-author. In addition, the comparison between researchers needs to take into account the time spent between entering the doctoral program and obtaining the doctoral degree, since older researchers generally tend to publish a greater number of articles, and therefore stand out in the academic world. On the other hand, researchers who completed their PHDs in 2020 are already part of this select group.

SCIENTIFIC PRODUCTIVITY OF DOCTORS IN REGIONAL DEVELOPMENT

Considering the variables related to Lotka's Law, Table 5 shows the x and y columns, where the x column represents the number of contributions by each author to the set of articles, while the y column indicates the number of authors. Thirty-nine authors contributed one article to the universe of publications; thirty-one authors contributed two articles, and so on. The xy column indicates the total number of articles produced.

The Log x and Log y columns are needed to calculate the parameter n (according to equation 3), which in turn is used to calculate the coefficient C (according to equation 2). The column Fe shows the expected theoretical frequency (according to equation 1), while the column Divergence represents the difference between y and Fe, i.e. the difference between the empirical frequency distribution and the theoretical distribution.

Finally, the Maximum diff. column is used to perform the Kolmogorov-Smirnov (K-S) test. This is a non-parametric method used to check whether there are significant differences between the observed frequencies and the theoretical or calculated frequencies of a distribution. Its interpretation is quite simple, with only two possibilities: the distribution fits (maximum diff. < critical value) or does not fit (maximum diff. > critical value) Lotka's Law, at a significance level of 0.01.

Table 5 | Frequency Distribution

x	y	xy	% y	Log x	Log y	Fe* = C(1/x^n)	Divergence	Maximum Diff.
1	39	39	17,81	0,0000	1,5911	0,5664	38,4336	0,1755
2	31	62	14,15	0,3010	1,4914	0,2827	30,7173	0,3158
3	23	69	10,50	0,4771	1,3617	0,1883	22,8117	0,4199
4	20	80	9,13	0,6021	1,3010	0,1411	19,8588	0,5106
5	13	65	5,94	0,6990	1,1139	0,1128	12,8872	0,5694
6	11	66	5,02	0,7782	1,0413	0,0940	10,9060	0,6192
7	15	105	6,85	0,8451	1,1761	0,0806	14,9194	0,6874
8	8	64	3,65	0,9031	0,9031	0,0704	7,9296	0,7236
9	6	54	2,74	0,9542	0,7782	0,0627	5,9374	0,7507
10	5	50	2,28	1,0000	0,6990	0,0563	4,9437	0,7733
11	1	11	0,46	1,0413	0,0000	0,0512	0,9488	0,7776
12	2	24	0,91	1,0791	0,3010	0,0002	1,9998	0,7865
13	0	0	0,00	1,1139	0,0000	0,0002	-0,0002	0,7863
14	4	56	1,83	1,1461	0,6021	0,0002	3,9998	0,8044
15	2	30	0,91	1,1761	0,3010	0,0002	1,9998	0,8134
16	4	64	1,83	1,2041	0,6021	0,0002	3,9998	0,8315
17	3	51	1,37	1,2304	0,4771	0,0002	2,9998	0,8450
18	2	36	0,91	1,2553	0,3010	0,0001	1,9999	0,8540
19	3	57	1,37	1,2788	0,4771	0,0001	2,9999	0,8676
20	3	60	1,37	1,3010	0,4771	0,0001	2,9999	0,8811
21	4	84	1,83	1,3222	0,6021	0,0001	3,9999	0,8993
22	3	66	1,37	1,3424	0,4771	0,0001	2,9999	0,9129
23	3	69	1,37	1,3617	0,4771	0,0001	2,9999	0,9264
24	0	0	0,00	1,3802	0,0000	0,0001	-0,0001	0,9263
25	3	75	1,37	1,3979	0,4771	0,0001	2,9999	0,9399
26	0	0	0,00	1,4150	0,0000	0,0001	-0,0001	0,9398
27	2	54	0,91	1,4314	0,3010	0,0001	1,9999	0,9489
28	2	56	0,91	1,4472	0,3010	0,0001	1,9999	0,9579
29	0	0	0,00	1,4624	0,0000	0,0001	-0,0001	0,9578
30	0	0	0,00	1,4771	0,0000	0,0001	-0,0001	0,9577
31	0	0	0,00	1,4914	0,0000	0,0001	-0,0001	0,9577
32	0	0	0,00	1,5051	0,0000	0,0001	-0,0001	0,9576
33	0	0	0,00	1,5185	0,0000	0,0001	-0,0001	0,9575
34	0	0	0,00	1,5315	0,0000	0,0001	-0,0001	0,9574
35	2	70	0,91	1,5441	0,3010	0,0001	1,9999	0,9665
36	0	0	0,00	1,5563	0,0000	0,0001	-0,0001	0,9664
37	0	0	0,00	1,5682	0,0000	0,0001	-0,0001	0,9663
38	1	38	0,46	1,5798	0,0000	0,0001	0,9999	0,9708
39	0	0	0,00	1,5911	0,0000	0,0001	-0,0001	0,9708
40	1	40	0,46	1,6021	0,0000	0,0001	0,9999	0,9753
41	0	0	0,00	1,6128	0,0000	0,0001	-0,0001	0,9752
42	0	0	0,00	1,6232	0,0000	0,0001	-0,0001	0,9752
43	0	0	0,00	1,6335	0,0000	0,0001	-0,0001	0,9751
44	0	0	0,00	1,6435	0,0000	0,0001	-0,0001	0,9750
45	1	45	0,46	1,6532	0,0000	0,0001	0,9999	0,9795
46	0	0	0,00	1,6628	0,0000	0,0001	-0,0001	0,9795
47	0	0	0,00	1,6721	0,0000	0,0001	-0,0001	0,9794
48	0	0	0,00	1,6812	0,0000	0,0001	-0,0001	0,9794
49	0	0	0,00	1,6902	0,0000	0,0001	-0,0001	0,9793
50	0	0	0,00	1,6990	0,0000	0,0001	-0,0001	0,9793
51	0	0	0,00	1,7076	0,0000	0,0001	-0,0001	0,9792
52	0	0	0,00	1,7160	0,0000	0,0000	0,0000	0,9792
53	0	0	0,00	1,7243	0,0000	0,0000	0,0000	0,9791
54	0	0	0,00	1,7324	0,0000	0,0000	0,0000	0,9791
55	0	0	0,00	1,7404	0,0000	0,0000	0,0000	0,9790
56	0	0	0,00	1,7482	0,0000	0,0000	0,0000	0,9790
57	0	0	0,00	1,7559	0,0000	0,0000	0,0000	0,9789
58	0	0	0,00	1,7634	0,0000	0,0000	0,0000	0,9789
59	1	59	0,46	1,7709	0,0000	0,0000	1,0000	0,9834
60	0	0	0,00	1,7782	0,0000	0,0000	0,0000	0,9834
61	0	0	0,00	1,7853	0,0000	0,0000	0,0000	0,9833
62	0	0	0,00	1,7924	0,0000	0,0000	0,0000	0,9833
63	0	0	0,00	1,7993	0,0000	0,0000	0,0000	0,9833
64	0	0	0,00	1,8062	0,0000	0,0000	0,0000	0,9832
65	0	0	0,00	1,8129	0,0000	0,0000	0,0000	0,9832
66	1	66	0,46	1,8195	0,0000	0,0000	1,0000	0,9877
TOTAL	219	1765	100,00	92,7359	17,9319	1,7107	217,2893	
Critical value								0,1101

* C = 0,0026; n= 1,0026

Source: Elaborated by the authors.

Based on the data presented in Table 5 and the principles of Lotka's Law, an analysis of the scientific productivity of PhDs working in the area of Regional Development reveals particularities regarding the form and distribution of this group's academic output. When looking at empirical data, it can be seen that only 17.81% of PhDs have produced a single article - a proportion that contrasts with the classic patterns observed by Lotka (1926), which indicated approximately 60% of authors with a single publication, and with similar findings from studies applied to other areas of knowledge.

The application of Lotka's Law assumes that the number of authors with n publications is approximately $1/n^2$ of those who have only published one article, i.e. scientific productivity would be concentrated in a few very productive authors, while the majority would have a low frequency of publications. However, the results obtained in this study indicate a departure from this pattern. The estimated parameters, n = 1.0026 and C = 0.0026, are far from the classic values of n = 2 and C = 0.6079. This discrepancy is corroborated by the results of the Kolmogorov-Smirnov Test (K-S), whose Maximum Difference (0.9877) significantly exceeds the critical value (0.1101), leading to the rejection of the hypothesis of compliance with Lotka's Law at a significance level of 1%.

These findings indicate that the distribution of the productivity of PhDs in Regional Development does not follow Lotka's distribution, suggesting that the dynamics of scientific production in this area has its own characteristics, distinct from other more consolidated areas. The fact that a significant proportion of researchers have published multiple times (thirty-one authors with two articles, twenty-three with three, and so on) shows a homogeneous pattern of production where the concentration of productivity in a few individuals is not as pronounced as in other areas.

This result can be interpreted from different perspectives. Firstly, the field of Regional Development is, by nature, multidisciplinary, integrating knowledge from applied social sciences, economics, geography, planning, public administration, among others. This diversity can encourage more egalitarian collaborations between researchers and more distributed co-authorship practices, which dilutes the concentration effect around a few names. Secondly, as an emerging and consolidating area in the Brazilian scientific scene, Regional Development may not yet have established the mechanisms of institutionalization and hierarchization of scientific production that,

in other areas, reinforce the centralization of authorship in more productive groups or individuals.

This study also differs from others that have confirmed the validity of Lotka's Law in different domains, such as nursing (Alvarado, 2006), information science (Sobrino et al., 2008), auditing (Mello et al., 2017) or biodiesel (Fernandes *et al*., 2020). In these fields, we observed the classic patterns of concentration of productivity, which can be explained by more mature disciplinary structures, consolidated research networks and greater academic competitiveness. On the other hand, the results of this research are in line with studies by Ahmad and Batcha (2020), in the field of dyslexia, and Tunga (2020), on horticulture; they also found Lotka's Law to be inadequate, potentially because these are fields with less consolidated publication dynamics.

The study by Brum and Dill (2024) also concludes that the productivity of professors-supervisors of PPGs in Regional Development does not fit Lotka's Law. This finding is reinforced by another study, by Dill, Allebrandt and Brum (2023), which shows that scientific production is less concentrated in a few authors and more distributed among PhDs in the area.

The data analyzed shows that the scientific productivity of PhDs in Regional Development is more evenly distributed, with a lower concentration of production by a few authors and a greater participation by a significant number of researchers with multiple contributions. This pattern may be associated with the epistemological and institutional specificities of the field, which favor a horizontal distribution of authorship and knowledge production. Such characteristics should be considered in future evaluations of academic performance in the field and in the formulation of policies to strengthen it, especially in institutional contexts that seek to encourage interdisciplinarity and collaboration among peers.

FINAL CONSIDERATIONS

Since the entry of the first class in 2002 and the defense of the first thesis in 2005, doctors in Regional Development have become agents behind the strengthening of this field in Brazil. By the end of 2020, two hundred and seventy-one PHDs had been awarded, whose academic work generated significant scientific output: 6,256 papers presented at events, 3,013 articles in periodicals, 1,450 book chapters and 575 books published or organized. Some of this production began even before they finished their training, with records dating back to 1977 - demonstrating the prior involvement in research by some of these professionals.

This study focused specifically on articles published after entering the doctorate and indexed in Qualis/CAPES (2013-2016 quadrennium), accounting for 1,765 publications by two hundred and nineteen doctors. This data shows that PhDs in Regional Development make a major contribution to scientific dissemination, although there are still obstacles to the full consolidation of the field.

Twenty-three years after the first admission and twenty years after the first graduation, we can see not only the quantitative growth of the Graduate Programs in Development, but also the increase in the number of graduates. Regional, but also the advancement of scientific production linked to its graduates. These doctors are key players in national scientific development, especially in the broad area of Urban and Regional Planning/Demography. However, their work must be understood as part of a broader process, as part of the expansion of higher education promoted by federal public policies in recent decades.

Despite the progress made, important challenges remain. The first concerns the non-conformity of scientific productivity of these PHDs with Lotka's Law. Production is still dispersed, without the consolidation of academic elite among graduates. The rise of young researchers as prominent figures, even among program professors, reveals a gap: no graduate student has assumed leadership in the field due to the quantity and impact of their production. The absence of the protagonists could jeopardize external recognition and the institutional continuity of the field. In this context, the commitment of current and future doctors to publish consistently becomes crucial.

Another worrying point is the low level of curricular updating and engagement on the part of graduates. Approximately 25% of doctors do not update their CVs on the Lattes Platform; some of

them are not even registered there. Although factors such as retirement and death must be taken into account, the scientific inactivity of a quarter of doctors in a universe that is already restricted, jeopardizes the dynamism and sustainability of the field. Added to this is the reduction in the number of graduates since 2018, which needs to be monitored and reversed in the upcoming cycles.

The second challenge relates to the quality of the journals chosen for their publications. Despite the growing appreciation of the higher strata of Qualis/CAPES in program evaluations, only 3.45% of published articles are classified as A1 and 6.2% as A2, while the rest are concentrated in the B strata. In addition, around 20% of doctors did not publish in indexed journals in the four-year period analyzed - a fact that demands attention and institutional strategies to encourage qualified publication.

The third challenge is the internationalization of scientific production. Although there have been recent efforts to publish in Spanish and English, the predominance of Portuguese is still evident. Contemporary science requires a mastery of English as the language of global circulation of knowledge. For doctors in the field, inclusion in international collaboration networks, fundraising and scientific recognition increasingly depend on overcoming this language barrier.

In order to strengthen the academic productivity of doctors in Regional Development, it would be necessary to implement policies that encourage the qualification of scientific production, the continuous engagement of graduates and the internationalization of research. Among the recommended actions are the creation of strategic research groups led by graduates, financial support for publication in high-impact journals, and encouragement for post-PHDs. The importance of creating an observatory to monitor doctors is also stressed.

In the field of internationalization, it is essential to encourage publications in English and Spanish by supporting the translation and revision of articles. Some strategic measures could be taken, in order to: include researchers in international collaboration networks; sign agreements with foreign universities; and support the indexing of journals in the field. In addition, we recommend the creation of academic recognition awards and the dissemination of performance indicators, promoting a culture of excellence and continuous evaluation within the postgraduate programs in Regional Development.

This preliminary study sought to shed light on the scientific performance of PhDs in Regional Development and stimulate debate on their responsibility for strengthening the field. The findings are expected to encourage further research exploring the relationship between productivity and variables such as gender, research scholarships or institutional links with PPGs. In addition, we would suggest applying Lotka's Law to journals specializing in Regional Development, as a way of gaining a deeper understanding of the dynamics of production in this area.

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