

Guatemala articles in the Science Citation Index Expanded: bibliometry of subjects, collaboration, institutions and authors

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Abstract: Guatemala, with 16 million inhabitants, is the largest economy of Central America and should have the largest scientific output of the region. To assess its productivity and impact, we analyzed the 3380 Guatemala articles included in the SCI-expanded in June, 2017. Most Guatemala documents are articles in English, deal with nutrition and health problems, and have a mean of 7.4 authors per article. Also in this particular database, citation lifespan is 40 years, and citations are higher for articles in English (twice more than those in Spanish), for reviews (mean 24 citations per review) and for studies resulting from international collaboration, which is done mostly with the USA and Mexico. The most productive institutions are the Center for Studies of Sensory Impairment (CESSIAM), the universities of San Carlos and El Valle, and the Central American Nutrition Institute (INCAP, but it has decreased productivity in recent years). The most productive researchers are N.W. Solomons, R. Bressani, L.G. Elías, C. Rolz and A. Cáceres. Guatemala represents a particular case in Central America because its high quality research is dependent on particular researchers rather than on institutions, and because the total output is well under the expectation. The productivity and citation of Guatemalan science in the 18 journals published in the country, and in other journals which are also not covered in the SCI-expanded, remain unknown. Nevertheless, the historical trend is positive, with a clear growth of international collaboration, productivity and citation. *Rev. Biol. Trop.* 66(1): 312-320. Epub 2018 March 01.

Key words: Web of Science, Latin American science, scientific output, most productive institutions and authors, research fields.

Guatemala, with 16 million inhabitants, is the largest economy of Central America and should have the largest scientific output of the region. However, this is not the case: with a per capita Gross Domestic Product of \$ 4000, Guatemala is below its neighbors Mexico (\$18000) and Honduras (\$ 4700). A series of dictatorships that started in 1871, and a genocidal civil war from 1960 to 1996, prevented the country from developing a proper scientific establishment and even from properly feeding its people (Marini & Gragnolati, 2003). For this reason, Guatemala does not occupy the expected place in the ranking of science in the Central American context.

Previous studies in this series have analyzed the scientific output of other Central American countries. One of the smallest countries in the isthmus, Costa Rica, leads the region with nearly 7000 publications in the database, about half of them produced in international collaboration and dominated by biology and medicine (Monge-Nájera & Ho, 2012). The second most productive Central American country is Panama, also a small country, with over 4800 publications that show strong collaboration with the USA and concentration on forest ecology (Monge-Nájera & Ho, 2015). The third and fourth places are occupied by the largest countries, Honduras and Nicaragua.

Honduras, with 1146 publications mostly about health and agriculture, is the Central American country with less scientific journals (Monge-Nájera & Ho, 2017b). Nicaragua has over 800 publications in the database, dominated by medical research in which Nicaraguan scientists play a secondary role within international teams (Monge-Nájera & Ho, 2017a). El Salvador, second smallest country in the region, is also among the less productive, with 788 publications mostly from the social sciences (Monge-Nájera & Ho, 2017c).

Even though there are no in-depth studies about the scientific output of Guatemala, it has been included in a series of larger studies from 1982 through 2015. In the transition from the decade of 1970 to that of 1980, Guatemala was increasing the number of articles included in the Science Citation Index (SCI) database (Blickenstaff & Moravcsik, 1982), but still that meant a low number of only 18 articles (Garfield, 1983). They had 96 citations in journals covered in the index, which led Garfield (1983) to place it in the world's middle impact category, despite the fact that in the SCI countries with very low numbers produce misleading results (for example, one country with 1 article and 5 citations is considered as successful as one with 1000 articles and 5000 citations, albeit clearly their real impact in world science is quite different).

In the decade of 1980, around 40 Guatemalan articles per year were included in the SCI and Guatemala occupied the 83rd. place in the list (Braun, Glanzel & Schubert, 1988; Lewison, Fawcett-Jones & Kessler, 1993), accumulating to 1993 nearly 600 articles, better than its similarly sized neighbor Honduras, which only had 108 articles (Garfield, 1995; Fernández, Gómez & Sebastian, 1998).

Considering the economically active population, Guatemala was just under the Latin American average in productivity (DeMoya-Anegón & Herrero-Solana, 1999), but this result, based on all scientific fields, did not include computing science, where Guatemala only had one article in the year 2007, just like Honduras, and far below Mexico, which had

5000 (Rojas-Sola & Jordá-Albiñana, 2009). Finally, the most recent study reported that Guatemala only has three Open Access scientific journals (Alonso & González, 2015).

MATERIALS AND METHODS

We used the Science Citation Index Expanded (SCI-EXPANDED), Web of Science Core Collection, Thomson Reuters. We searched for the word “Guatemala” in the address field and found 3 697 documents, published between 1900 and 2016 (Date of search: June 19th, 2017). Results were refined by countries/territories with Guatemala. We discarded 63 documents with “Guatemala” in the address field that were not actually from the country (for example USDA, Aphis, Guatemala Medfly Methods Stn, Usemb Aphis Unit 3319, Apo, AA 34024; Rua Guatemala, 190 Alto Rio Preto, BR-15020260 Sao Jose Do Rio Preto, SP, Brazil; and Ctr Dis Control, Ctr Infect Dis, Div Parasit Dis, Med Entomol Res Unit Guatemala, Atlanta, GA 30333). In total, 3634 documents were finally found as publications by authors from Guatemala (including several types of document). Only 2380 that were formal articles were further analysed.

For international collaborative documents, we reclassified articles from England, Scotland, Northern Ireland, and Wales as “United Kingdom” (UK). Articles from the Union of Soviet Socialist Republics (USSR) were checked and reclassified as being from Russia (Ho et al., 2016).

To investigate citations, five indicators C_{year} , TC_{year} , C_0 , $TCPY$, and CPP_{2016} were applied. The “impact of an article in recent year” is considered as the number of citation from Web of Science Core Collection of an article in the recent year only, C_{year} (Ho, 2012), for example 2016, is referred to as C_{2016} , and citations of articles are considered as the total number of citations since publication to the end of the recent year was referred to as TC_{year} (Wang et al., 2011; Chuang et al., 2011). C_0 , the total number of citations of an article in its publication year (Ho and Kahn, 2014). $TCPY$,

the citations per year ($TC_{\text{year}}/\text{year}$) (Ho, 2012). CPP_{2016} , citations per publication ($CPP_{2016} = TC_{2016}/TP$) (Ho, 2012; Elango & Ho, 2017).

Affiliations in Federal Republic of Germany (Fed Rep Ger) and German Democratic Republic (Ger Dem Rep) were reclassified as being from Germany (Ho, 2014). Affiliations in Zaire were checked and reclassified as from the Democratic Republic of the Congo (Dem Rep Congo) (Pouris & Ho, 2014). Affiliations in Yugoslavia were checked and reclassified as being from Slovenia (Ho, 2014). Affiliations in the Union of Soviet Socialist Republics (USSR) were checked and reclassified as being from Russia (Ho, 2012). Similarly, Acad Sci USSR were checked and reclassified as being from the Russian Acad Sci (Chuang & Ho, 2014).

Tables appear in Digital Appendix 1 and *additional* figures in Digital Appendix 2. References for the main text appear in the printed version, while references to literature cited only on tables and figures are included in their own digital appendix as “Additional References”.

RESULTS

Articles greatly dominate the Guatemalan presence in the SCIE, followed by meeting abstracts; all other publication types are minor in number (Fig. 1). The most cited types of publication in this database are reviews, with a mean of 24 citations, followed by proceedings (21 citations) and articles (19 citations); letters and meeting abstracts are seldom cited (Fig. 1, Table 1).

Correction notes have the highest number of authors, with a mean of ten authors per publication, followed by articles (7.4 authors), and meeting abstracts (6 authors; Table 1).

The majority of articles in this database are in English, followed by Spanish (10 %) and minimal numbers in French, Portuguese and German (Table 2). In comparison with those in Spanish, articles in English had twice the number of coauthors and received seven times more citations (Table 2).

Publications received most citations in the third year, and then citation falls gradually

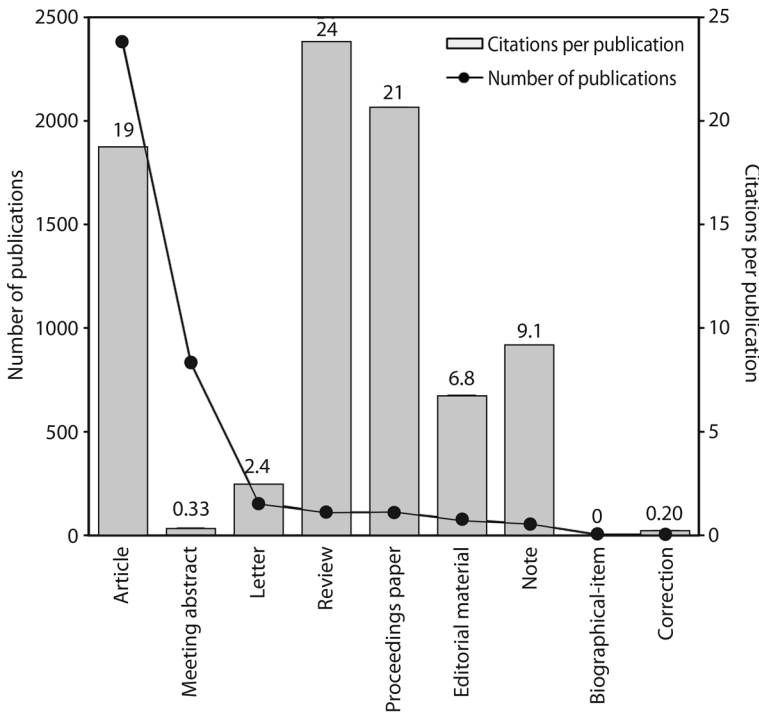


Fig. 1. Percentage of publications and number of journals in each Web of Science category.

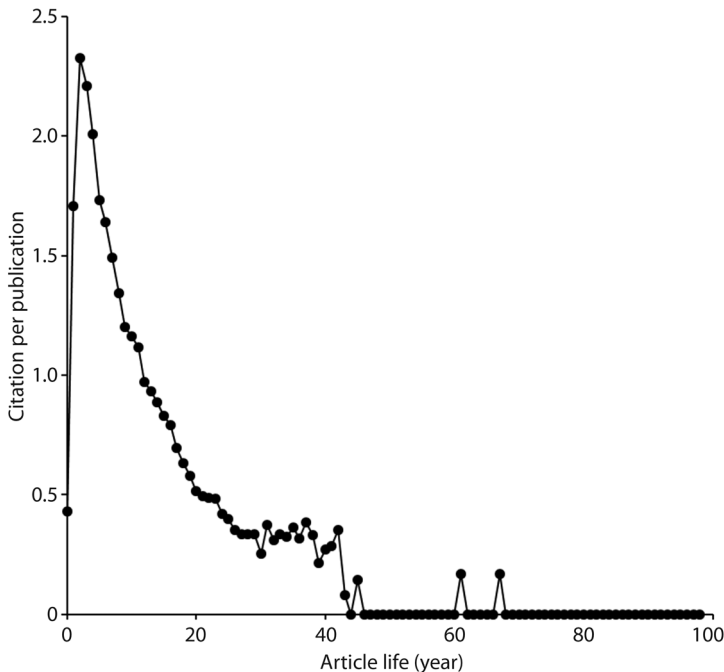


Fig. 2. Distribution of citations versus article age in years.

for three decades, reach a plateau in the fourth decade and articles basically stop being cited after 40 years (Fig. 2).

The SCIE records few citations for Guatemalan publications before 1970, when the literature mostly was not available in digital form, and afterwards peaked in output in the mid 1970s and again around the year 2000; in the same period citation has increased constantly since the 1990s (Fig. 3).

Both productivity and citation are higher for international publications than for strictly Guatemalan works (Fig. 4).

According to Web of Science categories, the highest percentage of publication are in the fields of Nutrition and dietetics; Public, environmental and occupational health; and Tropical medicine (Fig. 5), while distribution of publications by number of journals is dominated by Pharmacology, Plant Sciences and Public, environmental and occupational health (Fig. 5). Agriculture and nature receive little research attention (Table 3).

A larger number of publications appeared in journals from the nutrition and health categories, namely *Archivos Latinoamericanos de Nutrición*, *American Journal of Clinical Nutrition* and *American Journal of Tropical Medicine and Hygiene*; however there is no strong dominance, the journal with most articles (Archivos) only had 6.7 % (Table 4).

Collaboration with foreign institutions is on the rise in Guatemalan science, and the leading collaborators are institutions from the USA, Mexico and the United Kingdom (Fig. 6). The USA clearly dominated, with 49 % of papers, while most countries had 5 % or less (Table 5).

When only the geographically closest countries are analyzed, the rapid increase in collaboration stands out and the leading countries are in Central and South America (Fig. 7). Mexico co-produced 12 %, Costa Rica 5 % and Colombia 4 % (Table 5).

For the top cited articles, the historical citation pattern differs, some stay relatively constant before a final slow decline, some have clear peaks (Figure 8).

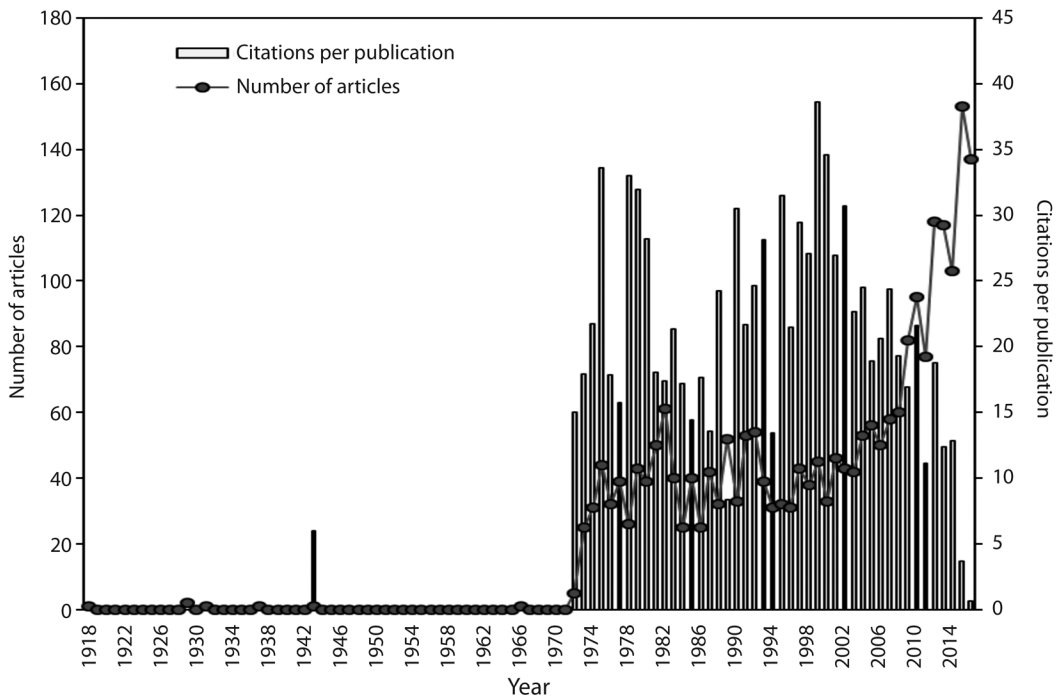


Fig. 3. Distribution of articles and citations per publication from 1918 through 2016.

Lifespan for top cited articles ranges from less than 2 to 14 years, but mostly is around 4 or 5 years (Fig. 9).

For the top cited articles in 2016, a value that has been established by Ho (2012) to allow for meaningful meta-analyses, the historical citation is a growing curve (Fig. 10) that also appears for top cited articles by total citation (Fig. 11) and for articles in both the top ten TC_{2016} and C_{2016} (Fig. 12).

Top producing Guatemalan institutions have three basic historical patterns: steady production (Center for Studies of Sensory Impairment, CESSIAM); rapid growth (Universities of San Carlos and del Valle), and strong reduction (Central American Nutrition Institute, INCAP; Figure 13). Even though it now has only a limited presence, in its early years the INCAP was a powerful institution that accumulated 21 % of all Guatemalan production in the SCIE. The public universities and the sensory impairment center CESSIAM

produced the other important proportions of publications (Table 6).

The top five researchers signing from Guatemalan institutions were N.W. Solomons, R. Bressani, L.G. Elias, C. Rolz and A. Cáceres (Table 7). Noel Solomons is the founder of the CESSIAM and an expert in the relationship between food and health; R. Bressani was the editor of the journal *Archivos Latinoamericanos de Nutrición* and a nutrition expert at INCAP; Luis G. Elías was also a nutrition expert at INCAP; C. Rolz is a chemical engineer at the Universidad del Valle who has worked in reducing the environmental impact of coffee and cane production; and A. Cáceres (Universidad de San Carlos) is an expert in the identification of medical compounds from Guatemalan plants.

When Web of Science categories are analyzed, the citation pattern oscillated widely with time, with no clear overall trend to increase or decrease (Fig. 14).

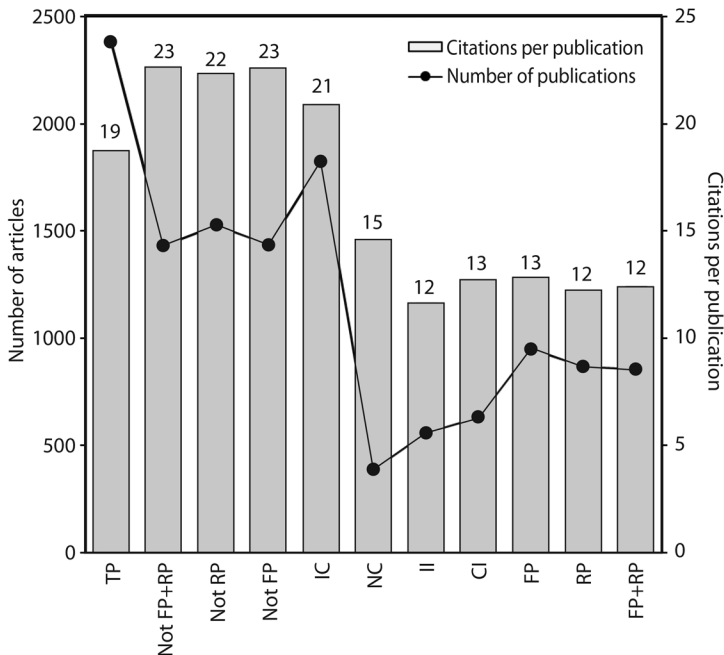


Fig. 4. Productivity and citation according to nationality in local and internationally produced articles. TP: total articles. Not FP+RP: both first and corresponding authors are not from Guatemala. Not RP: corresponding author is not from Guatemala. Not FP: first author is not from Guatemala. IC: internationally collaborative papers. NC: nationally collaborative papers. II: institutional independent papers. CI: Guatemala independent papers. FP: first author is from Guatemala. RP: corresponding author is from Guatemala. FP+RP: both first and corresponding authors are from Guatemala.

The overall top cited articles show a clear concentration in health, particularly nutrition (Table 8). The top cited articles deal with an international study of the human papillomavirus; and treatments for asthma, adenocarcinoma, diarrhea, pneumonia, influenza, psoriasis and hypertension (Table 8).

For publications in which all authors are from Guatemalan institutions, the top cited articles are about nutrition in children, clinical efficacy of ciprofloxacin and the anti-gonorrhoeal activity of Guatemalan plants (Table 9).

DISCUSSION

The domination of articles over other types of publication is typical of Latin American countries, and Guatemala is not an exception. The reason for this seems to be the fact that only articles qualify for salary improvement in Latin American universities (Sábato & Botana,

1993). The nearly universal use of English in the articles from Guatemala in the SCI-expanded does not reflect a characteristic of Guatemalan science, which produces many articles in Spanish, but reflects the fact that the SCI-expanded is biased against journals that are not in English and that are published outside the USA and Western Europe (Monge-Nájera, 2014). In fact, none of the 18 Guatemalan scientific journals are included in the SCI-expanded (<http://ip-science.thomsonreuters.com/cgi-bin/jrnlst/jloptions.cgi?PC=K>).

The fact that the SCI-expanded stops counting citations after the second year (Garfield, 2006) greatly affects Latin American science because most citations there take place after the second year (Monge-Nájera & Ho, 2012; 2015; 2017a-c). For those articles that are covered in the database, the patterns are also similar to those previously reported for other Central American countries, i.e. articles

in English are more cited because they have a larger readership, reviews are more cited because they summarize knowledge, and international projects are more cited because they are better funded and are of more general interest, usually in the field of health research (Monge-Nájera & Ho, 2017a-c).

The institutions with growing productivity in the database are universities with contrasting characteristics: the University of San Carlos, among the oldest in the continent (founded in 1676), is a public institution of 200 000 students, while Del Valle University is a small private institution (10 000 students) founded in 1966, but both are overcoming the disdain for publication typical of Guatemalan universities, thanks in part to the arrival of a new generation of researchers trained in Europe and the USA (Martínez-Folgar & Salomón, 2017).

The CESSIAM, a NGO with a steady production about the relationship of food and health founded in 1985, has always had research as key objective and has been under the same leadership for decades, which can explain why its output has remained good and stable over the years (<http://www.inffoundation.org/research/cessiam.htm>). Finally, the fall in productivity of the Central American Nutrition Institute, INCAP (www.incap.int), financed by the PAHO and private foundations, might reflect a change in leadership (M. Campos, pers. commun.).

The top authors from Guatemala match the list of top institutions, suggesting that they are the motivating leaders of productivity in their institutions. However, since they seem to have no peers of the same level in their institutions, those institutions may lose a significant part of their output if those particular scientists stop working for them, another known problem of science in Latin America (Nájera, Nielsen-Muñoz, & Azofeifa, 2010). A positive finding is, that contrary to other Central American countries (Monge-Nájera & Ho, 2017, a-c), Guatemalan authors are in some cases the leaders in the research teams signing high impact articles in the Science Citation Index.

Serious economic inequality, and a lack of interest in scientific research, keep Guatemala low in the Central American ranking of scientific productivity (Martínez-Folgar & Salomón, 2017); only Honduras has less articles in the database (Monge-Nájera & Ho, 2017b), but the growing trend in productivity and citation in the SCI-expanded is ground for optimism. The productivity and citation of Guatemalan science in the 18 journals published in the country, and in other journals also not covered in the SCI-expanded, remain unknown and must be borne in mind as a limitation of the present study, which did not include all of the scientific output of the country but only those documents that are included in the SCI-expanded. Previous work has shown that, for Latin American countries, the number of citations not included in the SCI-expanded may greatly outnumber citations in that database (Monge-Nájera, 2014).

In conclusion, Guatemala represents a particular case in Central America because its high quality research is highly dependent on particular researchers rather than on institutions, and because the total output is well under the expectation. Nevertheless, the historical trend is positive, with a clear growth of international collaboration, productivity and citation.

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RESUMEN

Artículos de Guatemala en el Science Citation Index Expanded: Bibliometría de sujetos, colaboración, instituciones y autores. Guatemala, con 16 millones de habitantes, es la mayor economía de Centroamérica y, por tanto, podría tener la mayor producción científica de la región. Para evaluar su productividad y su impacto, en junio 2017 analizamos los 3 380 artículos de Guatemala incluidos en el SCI-ampliado. La mayoría de los documentos de Guatemala son artículos en inglés, tratan problemas de nutrición y salud y tienen una media de 7.4 autores por artículo. También en esta base de datos en particular, los artículos siguen siendo citados durante 40 años, y se citan más los artículos en inglés (dos veces más que en español),

las revisiones (media: 24 citas por artículo de revisión) y los estudios resultantes de colaboración internacional, dominada por Estados Unidos y México. Las instituciones más productivas son el Centro de Estudios de Deterioro Sensorial CESSIAM, las universidades de San Carlos y del Valle, y el Instituto Centroamericano de Nutrición INCAP (pero el último ha disminuido la productividad en los últimos años). Los investigadores más productivos son N.W. Solomons, R. Bressani, L.G. Elías, C. Rolz y A. Cáceres. Guatemala representa un caso particular en Centroamérica, porque su investigación de alta calidad depende en gran medida de investigadores particulares, no tanto de las instituciones, y porque la producción total está muy por debajo de las expectativas para un país con esa población. La productividad y el impacto de la ciencia guatemalteca en las 18 revistas publicadas en el país, y en otras revistas que tampoco están cubiertas en el SCI-ampliado, siguen siendo desconocidos. Sin embargo, la tendencia histórica es positiva, con un claro crecimiento de la colaboración internacional, la productividad y el impacto.

Palabras clave: Web of Science, ciencia latinoamericana, productividad científica, autores e instituciones más productivas, campos de investigación.

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Digital Appendix 1: Tables

Table 1. Citations and authors according to document type.

Document type	<i>TP</i>	%	<i>TC</i> ₂₀₁₆	<i>CPP</i> ₂₀₁₆	<i>AU</i>	<i>AU/TP</i>
Article	2 380	65	44 498	19	17 696	7.4
Meeting abstract	832	23	273	0.33	4 972	6.0
Letter	160	4.4	389	2.4	430	2.7
Review	112	3.1	2 665	24	626	5.6
Proceedings paper	109	3.0	2 251	21	523	4.8
Editorial material	77	2.1	520	6.8	408	5.3
Note	54	1.5	494	9.1	178	3.3
Biographical-item	5	0.14	0	0	9	1.8
Correction	5	0.14	1	0.20	51	10
Book review	3	0.083	0	0	3	1.0
News item	3	0.083	20	6.7	13	4.3
Book chapter	1	0.028	0	0	1	1.0
Discussion	1	0.028	0	0	1	1.0
Item about an individual	1	0.028	0	0	3	3.0
Retraction	1	0.028	0	0	2	2.0

TP: number of articles; *AU*: number of authors; *TC*₂₀₁₆: total citations since publication to the end of 2016; *CPP*₂₀₁₆: citations per paper (*TC*₂₀₁₆/*TP*).

Table 2. Citations and authors according to document language.

Language	TP	%	TC_{2016}	CPP_{2016}	AU	AU/TP
English	2 124	89	43 765	21	16 768	7.9
Spanish	241	10	663	2.8	866	3.6
French	12	0.50	55	4.6	54	4.5
Portuguese	2	0.084	5	2.5	5	2.5
German	1	0.042	10	10	3	3.0

TP : number of articles; AU : number of authors; TC_{2016} : total citations since publication to the end of 2016; CPP_{2016} : citations per paper (TC_{2016}/TP).

Table 3. Web of Science category.

Web of Science category	<i>TP</i>	%	No. Journals
Nutrition and Dietetics	498	21	81
Public, Environmental and Occupational Health	299	13	176
Tropical Medicine	192	8.1	19
Pediatrics	147	6.2	121
Infectious Diseases	132	5.5	84
Food Science and Technology	125	5.3	129
Plant Sciences	102	4.3	211
Parasitology	89	3.7	36
Immunology	87	3.7	150
Pharmacology and Pharmacy	84	3.5	256
Microbiology	78	3.3	124
Entomology	76	3.2	91
Agronomy	71	3.0	83
Multidisciplinary Sciences	65	2.7	64
Environmental Sciences	64	2.7	229
Obstetrics and Gynecology	62	2.6	80
Biotechnology and Applied Microbiology	61	2.6	158
General and Internal Medicine	56	2.4	154
Oncology	55	2.3	217
Applied Chemistry	52	2.2	72
Dentistry, Oral Surgery and Medicine	52	2.2	90

TP: number of articles

Table 4. Journals.

Journals	<i>TP</i> (%)	<i>IF</i> ₂₀₁₆	Web of Science cate
Archivos Latinoamericanos de Nutricion	160 (6.7)	0.459	Nutrition and Dieteti
American Journal of Clinical Nutrition	99 (4.2)	6.926	Nutrition and Dieteti
American Journal of Tropical Medicine and Hygiene	92 (3.9)	2.549	Public, Environment; Tropical Medicine
Journal of Nutrition	43 (1.8)	4.145	Nutrition and Dieteti
Plos One	36 (1.5)	2.806	Multidisciplinary Sci
Turrialba	26 (1.1)	N/A	Agronomy
European Journal of Clinical Nutrition	20 (0.84)	3.057	Nutrition and Dieteti
Journal of Ethnopharmacology	20 (0.84)	2.981	Plant Sciences Chemistry, Medicina Integrative and Comj Pharmacology and Pl
Ecology of Food and Nutrition	19 (0.8)	0.922	Nutrition and Dieteti
Boletin de la Oficina Sanitaria Panamericana	18 (0.76)	N/A	Public, Environment;
Food and Nutrition Bulletin	18 (0.76)	1.648	Food Science and Te Nutrition and Dieteti
Journal of Pediatric Gastroenterology and Nutrition	18 (0.76)	2.799	Gastroenterology and Nutrition and Dieteti Pediatrics
Transactions of the Royal Society of Tropical Medicine and Hygiene	18 (0.76)	2.279	Public, Environment; Tropical Medicine
Reproductive Health	17 (0.71)	2.209	Public, Environment;
Florida Entomologist	16 (0.67)	0.964	Entomology
Journal of Food Science	16 (0.67)	1.815	Food Science and Te
Nutrition Research	16 (0.67)	2.737	Nutrition and Dieteti
American Journal of Physical Anthropology	15 (0.63)	2.552	Anthropology Evolutionary Biology
Journal of Infectious Diseases	15 (0.63)	6.273	Immunology

TP: number of articles; *IF*₂₀₁₆: impact fact in 2016; N/A: not avalable

Table 5. Country

Country	<i>TP</i>	<i>TP R (%)</i>	<i>FP R (%)</i>	<i>RP R (%)</i>
USA	1 176	1 (49)	1 (33)	1 (32)
Mexico	280	2 (12)	2 (3.7)	2 (3.9)
UK	167	3 (7.0)	4 (2.3)	4 (2.5)
Brazil	140	4 (5.9)	5 (2.0)	5 (2.0)
Costa Rica	126	5 (5.3)	10 (1.0)	10 (1.1)
Spain	125	6 (5.3)	3 (3.0)	3 (3.3)
Argentina	119	7 (5.0)	14 (0.80)	14 (0.82)
Colombia	104	8 (4.4)	10 (1.0)	10 (1.1)
Germany	97	9 (4.1)	6 (1.6)	6 (1.7)
Canada	86	10 (3.6)	7 (1.4)	7 (1.5)
France	83	11 (3.5)	8 (1.1)	8 (1.2)
El Salvador	80	12 (3.4)	37 (0.042)	37 (0.046)
Chile	72	13 (3.0)	18 (0.46)	17 (0.55)
Honduras	70	14 (2.9)	21 (0.25)	20 (0.27)
Peru	68	15 (2.9)	32 (0.084)	30 (0.092)
India	67	16 (2.8)	32 (0.084)	30 (0.092)
Italy	64	17 (2.7)	13 (0.84)	13 (0.87)
Netherlands	63	18 (2.6)	16 (0.67)	15 (0.73)
Switzerland	61	19 (2.6)	12 (0.92)	12 (0.92)
Panama	56	20 (2.4)	25 (0.21)	23 (0.23)

TP: number of articles; *FP*: number of first author articles; *TP*: number of corresponding author articles; *R*: rank

Table 6. Institutions in Guatemala.

Institute		<i>TP</i>	<i>TP R</i>	<i>SP R</i>	<i>CP R</i>	<i>FP R (%)</i>	<i>RP R (%)</i>
		(%)	(%)	(%)	(%)		
Instituto de Nutrición de Centro América y Panamá (INCAP)	602	1 (25)	1 (53)	2 (17)	1 (16)	1 (16)	
Universidad de San Carlos	359	2 (15)	3 (5.5)	1 (18)	2 (3.5)	3 (3.1)	
Universidad del Valle, Guatemala	332	3 (14)	2 (7.3)	3 (16)	3 (3.4)	2 (3.4)	
Center Studies Sensory Impairment Aging & Metabolism	143	4 (6.0)	5 (3.2)	4 (6.9)	4 (2.7)	4 (2.8)	
Ministerio de Salud Pública y Asistencia Social	87	5 (3.7)	12 (0.71)	5 (4.6)	14 (0.21)	15 (0.18)	
Hospital General San Juan de Dios	53	6 (2.2)	6 (1.8)	7 (2.4)	6 (0.63)	6 (0.60)	
Universidad Francisco Marroquín	52	7 (2.2)	13 (0.53)	6 (2.7)	8 (0.46)	7 (0.50)	
Hospital Roosevelt	40	8 (1.7)	7 (1.4)	8 (1.8)	7 (0.5)	7 (0.50)	
Central American Research Institute for Industry	36	9 (1.5)	4 (5.3)	32 (0.33)	5 (1.3)	5 (1.4)	
Centers Disease Control & Prevention, Salvador Office	22	10 (0.92)	N/A	9 (1.2)	19 (0.13)	18 (0.14)	
Unidad Nacional de Oncología y Pediatría	17	11 (0.71)	N/A	10 (0.93)	45 (0.042)	N/A	
Hospital Herrera Llerandi	14	12 (0.59)	N/A	11 (0.77)	N/A	N/A	
Hospital Ojos y Oídos Dr. Rodolfo Robles V.	13	13 (0.55)	8 (1.2)	32 (0.33)	10 (0.29)	10 (0.32)	
Universidad Rafael Landívar	13	13 (0.55)	N/A	12 (0.71)	45 (0.042)	43 (0.046)	
Instituto de Etnobiología	12	15 (0.50)	N/A	13 (0.66)	N/A	N/A	
Servicio Nacional de Control de Enfermedades Transmitidas por Vectores Artrópodos	12	15 (0.50)	15 (0.36)	17 (0.55)	19 (0.13)	18 (0.14)	

TP: number of articles; *SP*: number of single institute articles; *CP*: number of inter-institutionally collaborative articles; *FP*: number of first author articles; *RP*: number of corresponding author articles; *R*: rank; N/A: not available

Table 7. Authors from Guatemala.

Author	Affiliation	TP	Rank (TP)	Rank (FP)
Solomons, NW	CeSSIAM	208	1 (208)	1 (65)
Bressani, R	Inst Invest	178	2 (178)	2 (55)
Elias, LG	Inst Nutr Cent Amer y Panamá	63	3 (63)	26 (6)
Rolz, C	Univ Valle Guatemala	52	4 (52)	3 (22)
Cáceres, A	Univ San Carlos USAC	45	5 (45)	8 (15)
Torun, B	INCAP	44	6 (44)	6 (16)
Garces, A	Francisco Marroquín Univ	39	7 (39)	48 (4)
Ramírez-Zea, M	Inst Nutr Cent América y Panamá INCAP	37	8 (37)	86 (3)
Habicht, JP	Inst Nutr Cent Amér y Panamá	35	9 (35)	86 (3)
Lechtig, A	Inst Nutr Cent Amér y Panamá	34	10 (34)	6 (16)
Yarbrough, C	Inst Nutr Cent Amér y Panamá	34	10 (34)	86 (3)
Vossenaar, M	CeSSIAM	33	12 (33)	10 (13)
Braham, JE	Inst Nutr Cent Amér y Panamá	32	13 (32)	86 (3)
Mazariegos, M	Inst Nutr Cent Amér y Panamá	32	13 (32)	19 (7)
Delgado, H	Inst Nutr Cent Amér y Panamá	29	15 (29)	48 (4)
Cruz, JR	Inst Nutr Cent Amér y Panamá	28	16 (28)	4 (18)
Barnoya, J	Cardiovasc Unit Guatemala	26	17 (26)	38 (5)
Monroy, C	Univ San Carlos	26	17 (26)	48 (4)
Zea-Flores, G	Ministerio de Salud de Guatemala	25	19 (25)	354 (1)
Bulux, J	Hosp Ojos y Oídos Dr. Rodolfo Robles V.	24	20 (24)	38 (5)
Pineda, O	Inst Nutr Cent Amér y Panamá	24	20 (24)	153 (2)
Lindblade, KA	CDC Reg Off Cent Amer & Panama	23	22 (23)	38 (5)
Molina, MR	Inst Nutr Cent Amér y Panamá	23	22 (23)	9 (14)
Belizan, JM	Inst Nutr Cent Amér y Panamá	21	24 (21)	17 (8)
Dearriola, MC	Cent Amer Inst Res Ind	20	25 (20)	354 (1)

TP: number of articles; FP: number of first author articles; RP: number of corresponding author articles; RP: number of single author articles; R: rank.

Table 8. Top 20 articles with over 200 total citations until the year 2016 ($TC_{2016} > 200$).

Rank (TC_{2016})	Rank (C_0)	Rank (C_{2016})	Rank (TC_{PY})	Title	Country
1 (676)	180 (1)	3 (139)	2 (97)	Human papillomavirus genotype attribution in invasive cervical cancer: a retrospective cross-sectional worldwide study	Spain, Netherlands, Portugal, Colombia, Korea, Peru, Mexico, Brazil, Taiwan, Paraguay, Bosnia & Herzegovina, Uganda, Lebanon, Croatia, Turkey, India, Guatemala, Nigeria, Philippines, Bangladesh, Thailand, Australia, Japan, Honduras, Algeria, Republic, USA, Kuwait, Greece, Venezuela, Poland, Israel
2 (409)	13 (9)	72 (8)	16 (23)	Oral montelukast, inhaled beclomethasone, and placebo for chronic asthma - A randomized, controlled trial	USA, Costa Rica, Guatemala, Peru
3 (402)	1 (60)	1 (200)	1 (134)	Ramucirumab monotherapy for previously treated advanced gastric or gastro-oesophageal junction adenocarcinoma (REGARD): an international, randomised, multicentre, placebo-controlled, phase 3 trial	USA, Czech Republic, South Korea, India, Brazil, UK, Canada, Russia, Guatemala, Poland, Spain
4 (397)	47 (3)	35 (12)	17 (22)	Prevention of diarrhea and pneumonia by zinc supplementation in children in developing countries: Pooled analysis of randomized controlled trials	USA, Pakistan, Jamaica, UK, Indonesia, Bangladesh, Vietnam, Peru, Mexico, India
5 (392)	2 (41)	6 (66)	4 (78)	A distinct lineage of influenza A virus from bats	USA, Guatemala
6 (311)	79 (2)	115 (6)	63 (7.2)	Height and weight standards for preschool-children - how relevant are ethnic differences in growth potential	Guatemala
7 (309)	180 (1)	1088 (0)	50 (8.1)	Assessment of zinc and copper nutrition in man	Guatemala
8 (305)	475 (0)	41 (10)	21 (18)	Therapeutic effects of oral zinc in acute and persistent diarrhea in children in developing countries: pooled analysis of randomized controlled trials	USA, Pakistan, UK, Jamaica, Indonesia, Bangladesh, Vietnam, Peru, Mexico, India
9 (260)	17 (7)	2 (146)	3 (87)	Secukinumab in Plaque Psoriasis - Results of Two Phase 3 Trials	Canada, USA, Germany, UK, Spain, Australia, Iceland, Guatemala, Taiwan
10 (256)	475 (0)	648 (1)	65 (7.1)	Studies on the bioavailability of zinc in humans - effects of heme and nonheme iron on the absorption of zinc	USA, Guatemala
11 (255)	30 (4)	648 (1)	59 (7.5)	Reduction of blood-pressure with calcium supplementation in young-adults	USA, Guatemala
12 (254)	475 (0)	150 (5)	69 (6.9)	The effect of a supportive companion on perinatal problems, length of labor, and mother-infant interaction	USA, Guatemala
13 (239)	475 (0)	5 (67)	6 (48)	Averting biodiversity collapse in tropical forest	Australia, Panama, UK, USA, Mexico, China, Canada, Denmark, Surinam,

				protected areas	France, Thailand, Congo, India, Net Costa Rica, Uganda, Italy, Austria, ' Bolivia, Taiwan, Venezuela, Singap Spain, Kenya, Cote Ivoire, Japan, G Republic, Papua N Guinea, Indones Sierra Leone, Cent Afr Republ, Nep
14 (235)	475 (0)	115 (6)	82 (6.2)	Analysis of two genetic models for the innate components of colony odor in social Hymenoptera	Australia, Guatemala
15 (227)	10 (10)	423 (2)	35 (11)	An outbreak in 1996 of cyclosporiasis associated with imported raspberries	USA, Canada, Guatemala
16 (220)	475 (0)	423 (2)	73 (6.7)	Heterogeneous growth and mental-development of intrauterine growth-retarded infants during the first three years of life	USA, Guatemala
17 (214)	475 (0)	648 (1)	121 (5.1)	Effect of food supplementation during pregnancy on birth-weight	Guatemala
18 (207)	475 (0)	1088 (0)	132 (4.9)	Acute morbidity and physical growth in rural Guatemalan children	Guatemala, USA
19 (202)	17 (7)	13 (36)	15 (25)	Ancestry Informative Marker Sets for Determining Continental Origin and Admixture Proportions in Common Populations in America	USA, Guatemala, Sweden
19 (202)	30 (4)	41 (10)	24 (16)	Miltefosine for New World cutaneous leishmaniasis	Germany, Colombia, Guatemala, U:

*TC*₂₀₁₆: total citations since publication to the end of 2016; *C*₀: citations in publication year; *C*₂₀₁₆: citations in 2016;
TCPY: citations per number of years.

Table 9. Top 10 Guatemala independent articles with $TC_{2016} > 100$.

Rank (TC_{2016})	Rank (C_0)	Rank (C_{2016})	Rank ($TCPY$)	Title	Institution
6 (311)	79 (2)	115 (6)	63 (7.2)	Height and weight standards for preschool-children - how relevant are ethnic differences in growth potential	Inst Nutr Cent Amer y Pa
7 (309)	180 (1)	1088 (0)	50 (8.1)	Assessment of zinc and copper nutriture in man	Inst Nutr Cent Amer y Pa
17 (214)	475 (0)	648 (1)	121 (5.1)	Effect of food supplementation during pregnancy on birth-weight	Inst Nutr Cent Amer y Pa
27 (166)	475 (0)	276 (3)	107 (5.4)	Competitive interaction of iron and zinc in the diet - consequences for human-nutrition	Inst Nutr Cent Amer y Pa Sensory Impair Aging & I
29 (164)	475 (0)	115 (6)	156 (4.4)	The relationship between calcium intake and edema-gestosis, proteinuria-gestosis, and hypertension-gestosis - an hypothesis	Inst Nutr Cent Amer y Pa
33 (153)	475 (0)	423 (2)	113 (5.3)	Hematological effect of supplementing anemic children with vitamin-a alone and in combination with iron	Inst Nutr Cent Amer y Pa
34 (148)	475 (0)	276 (3)	223 (3.5)	Vot discrimination by 4 to 6 1/2 month-old infants from spanish environments	Inst Nutr Cent Amer y Pa
57 (121)	475 (0)	648 (1)	267 (3.2)	Possible effects of seed coat polyphenolics on the nutritional quality of bean protein	Inst Nutr Cent Amer y Pa
58 (118)	475 (0)	648 (1)	209 (3.7)	Open, prospective-study of the clinical efficacy of ciprofloxacin	Roosevelt Hosp; San Juar
68 (102)	475 (0)	115 (6)	144 (4.6)	Antigonorrhoeal activity of plants used in Guatemala for the treatment of sexually-transmitted diseases	Univ San Carlos; Farmay;

TC_{2016} : total citations since publication to the end of 2016; C_0 : citations in publication year; C_{2016} : citations in 2016; $TCPY$: citations per number of years.

Digital Appendix 2. Additional Figures

Figure 5. Percentage of publications and number of journals in each Web of Science category.

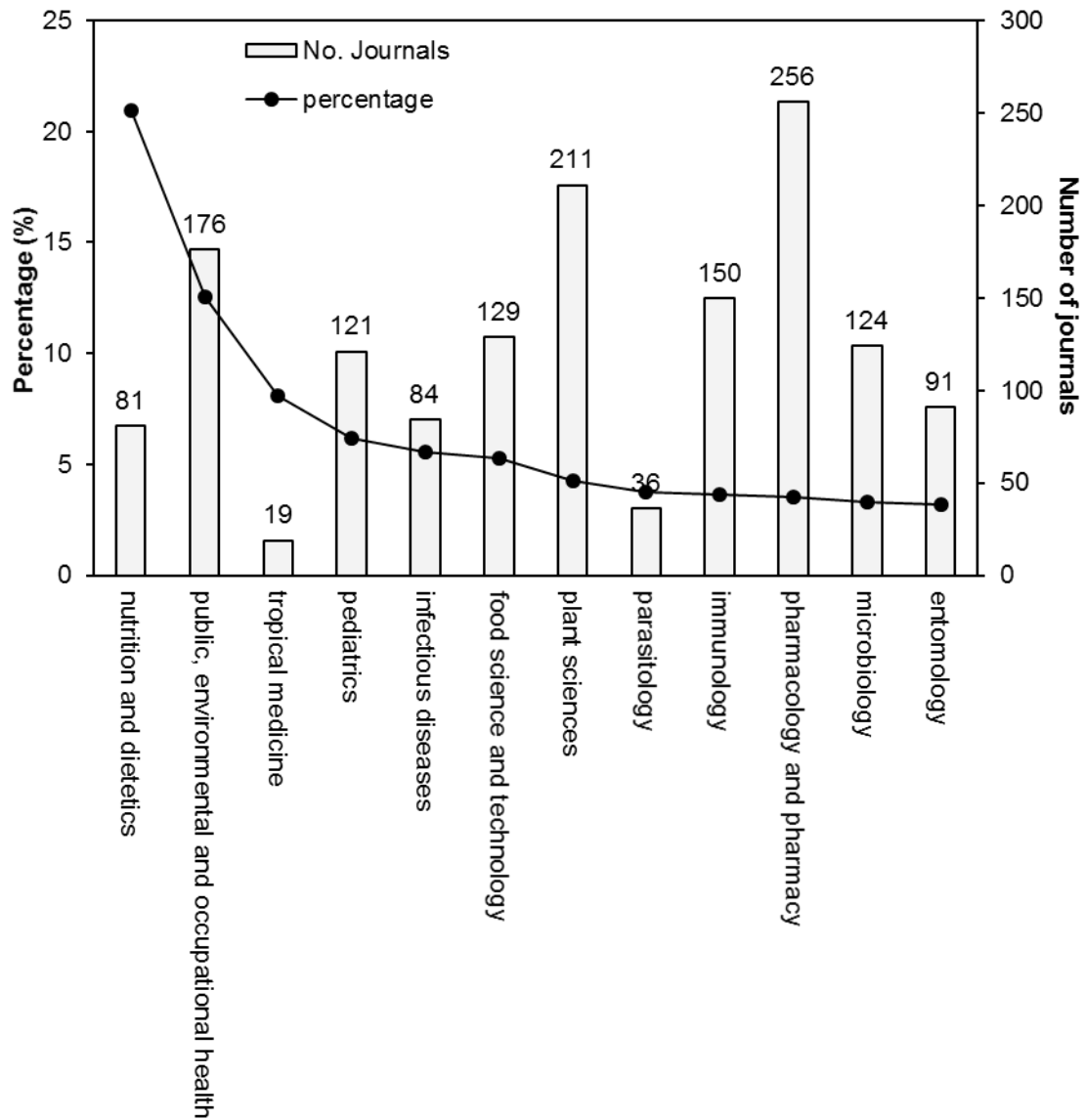


Figure 6. Historical collaboration pattern for the top six collaborative countries with Guatemala ($TP > 120$).

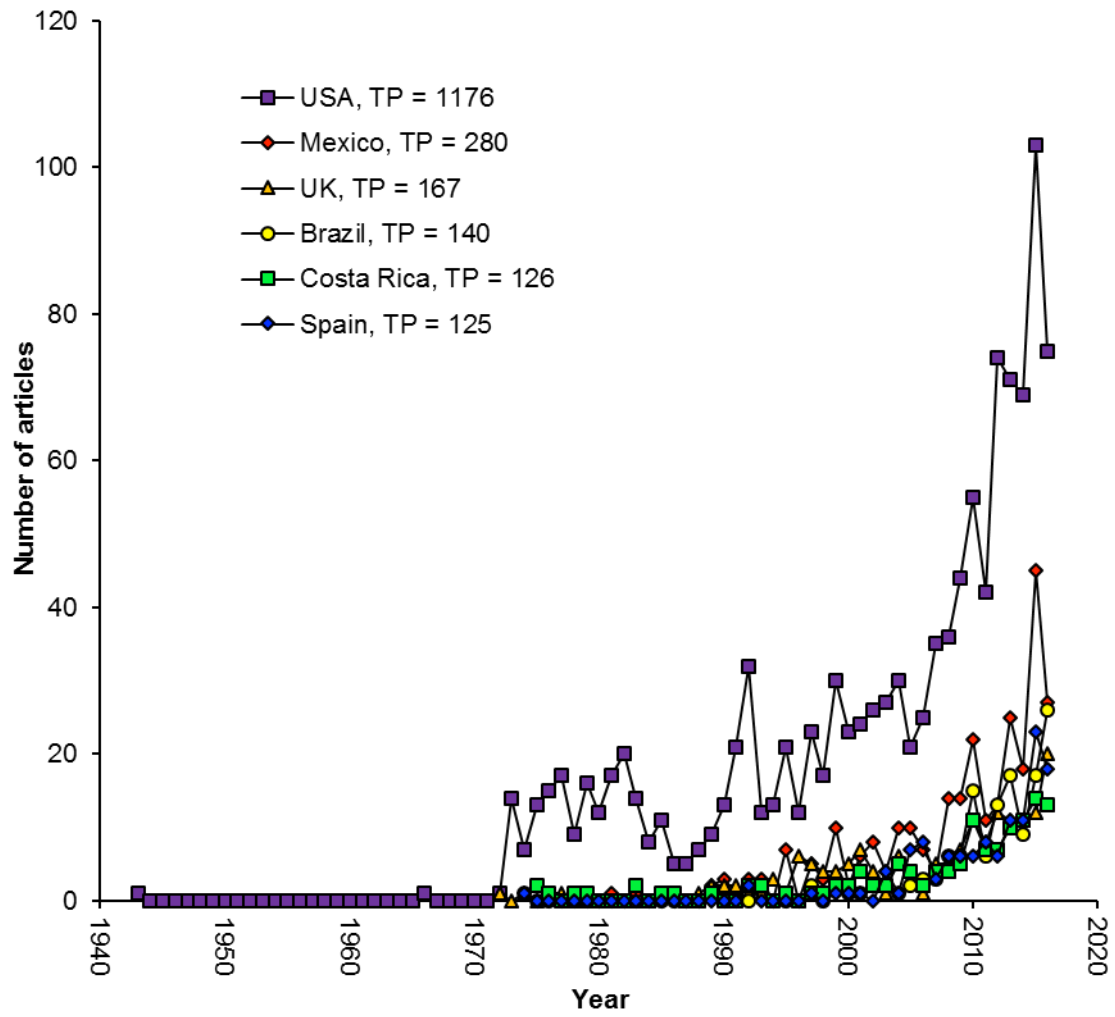


Figure 7. Historical collaboration pattern for Guatemala, by geographically closest countries.

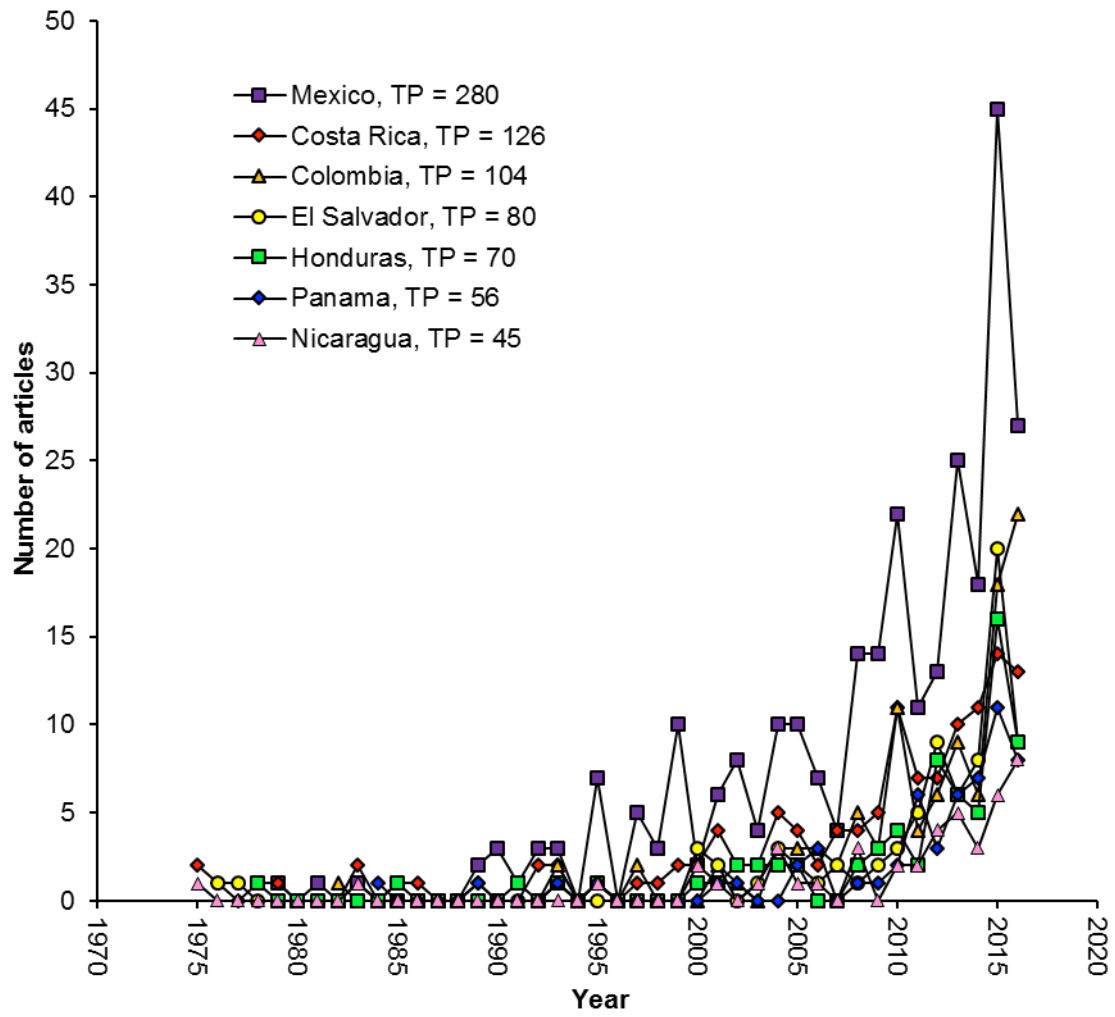


Figure 8. Historical citation patterns for top cited articles, by publication year ($C_0 > 10$).

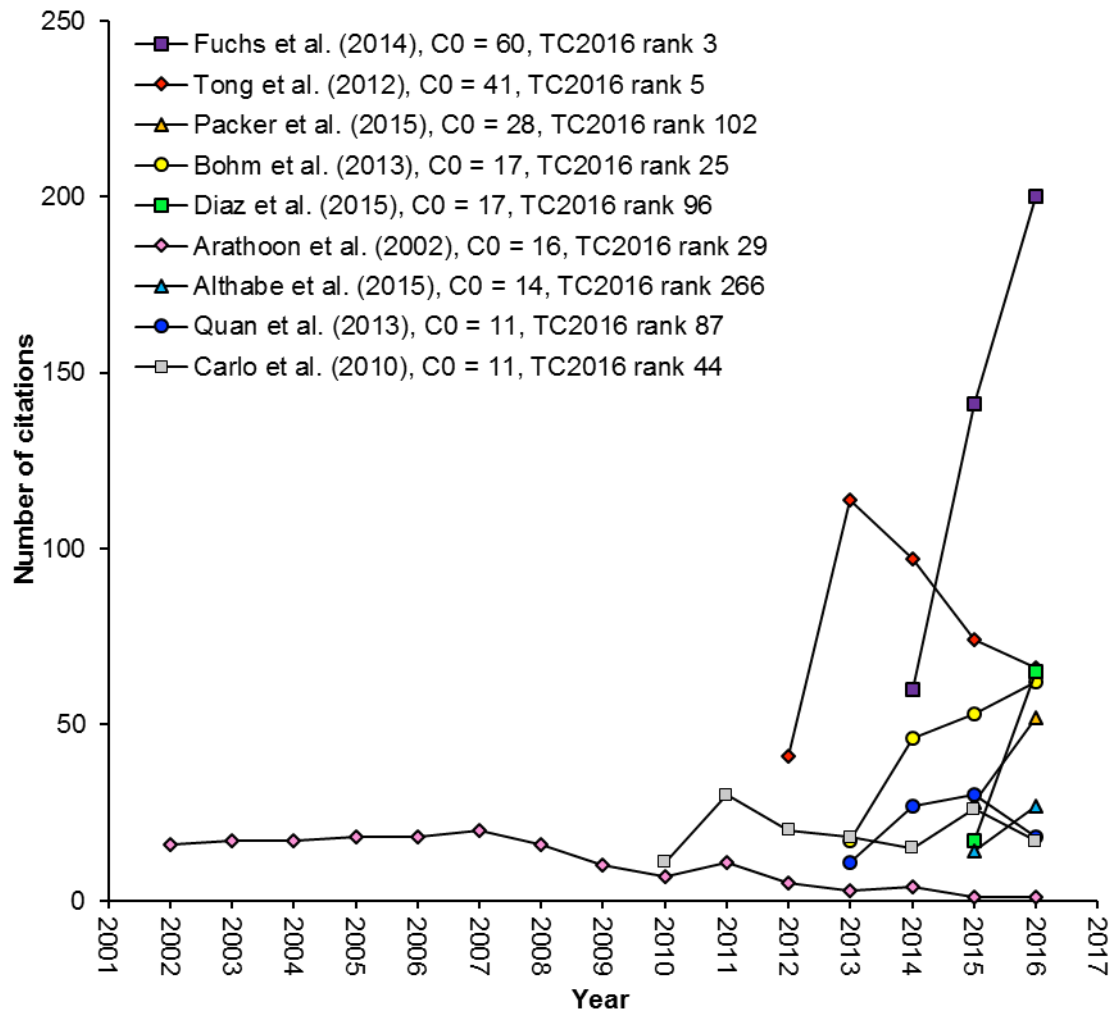


Figure 9. Article lifespan for top cited articles, by publication year ($C_0 > 10$).

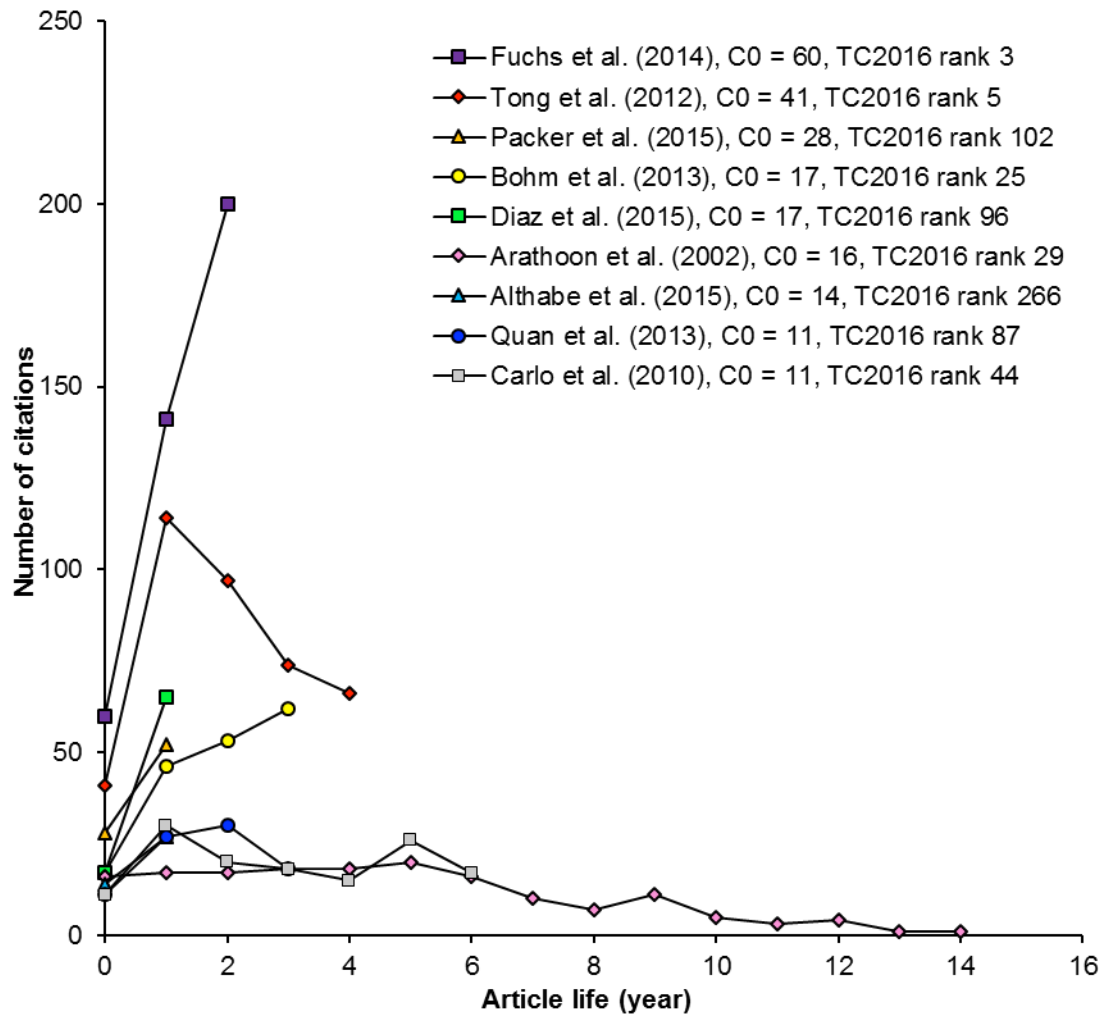


Figure 10. Historical citation patterns for top cited articles in 2016 (recent year) only ($C_{2016} > 50$).

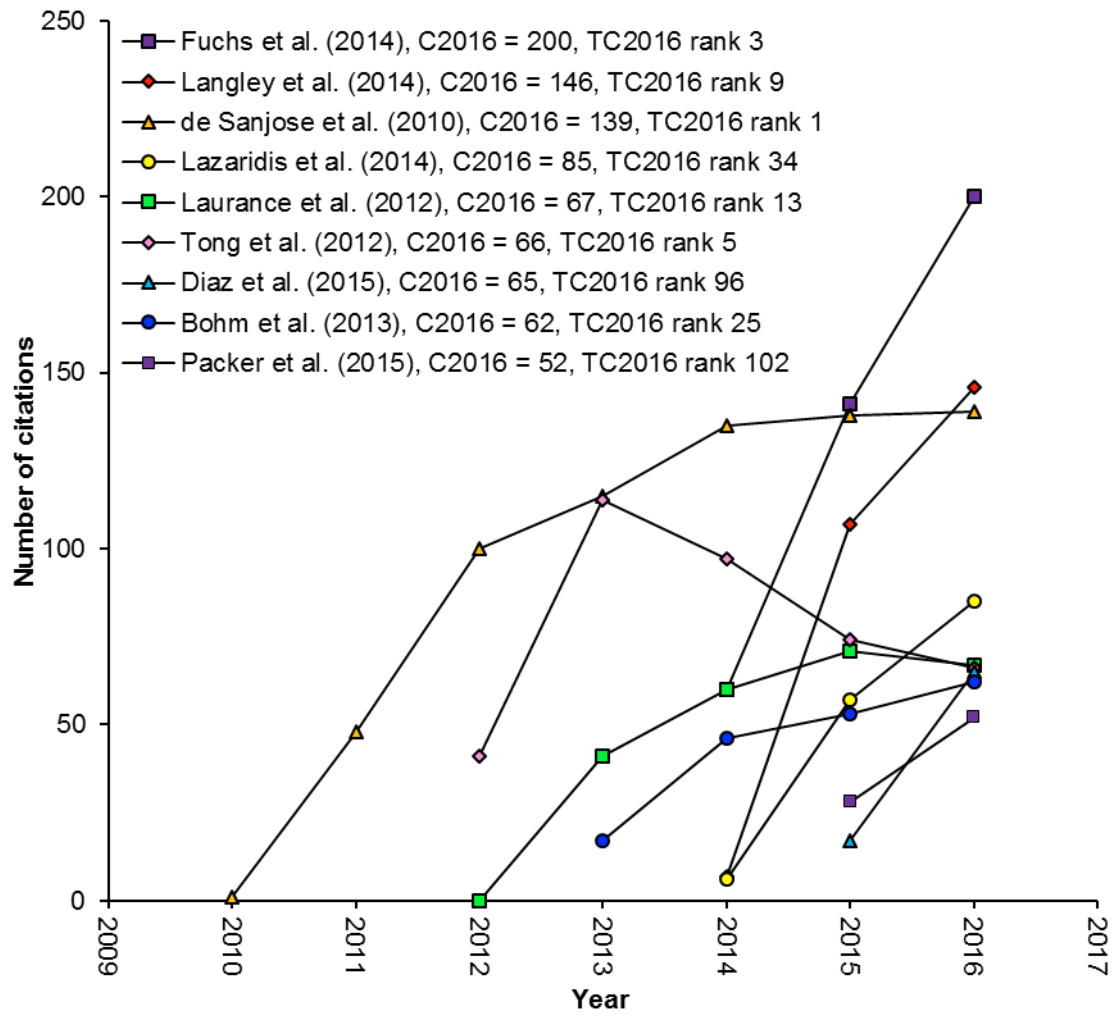


Figure 11. Historical citation patterns for top cited articles by total citations per year ($TCPY \geq 40$).

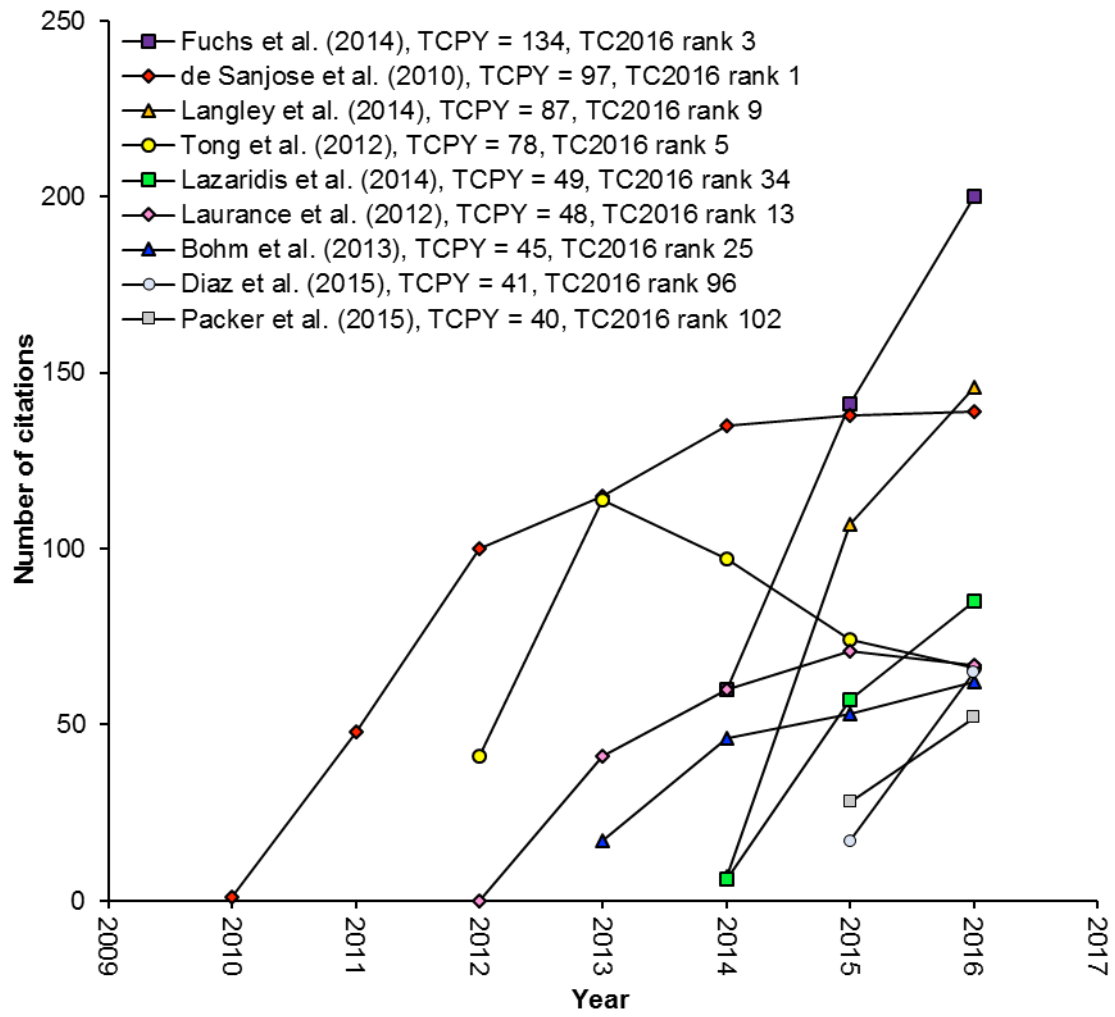


Figure 12. Historical citation patterns for four articles ranked on both the top ten TC_{2016} and C_{2016} .

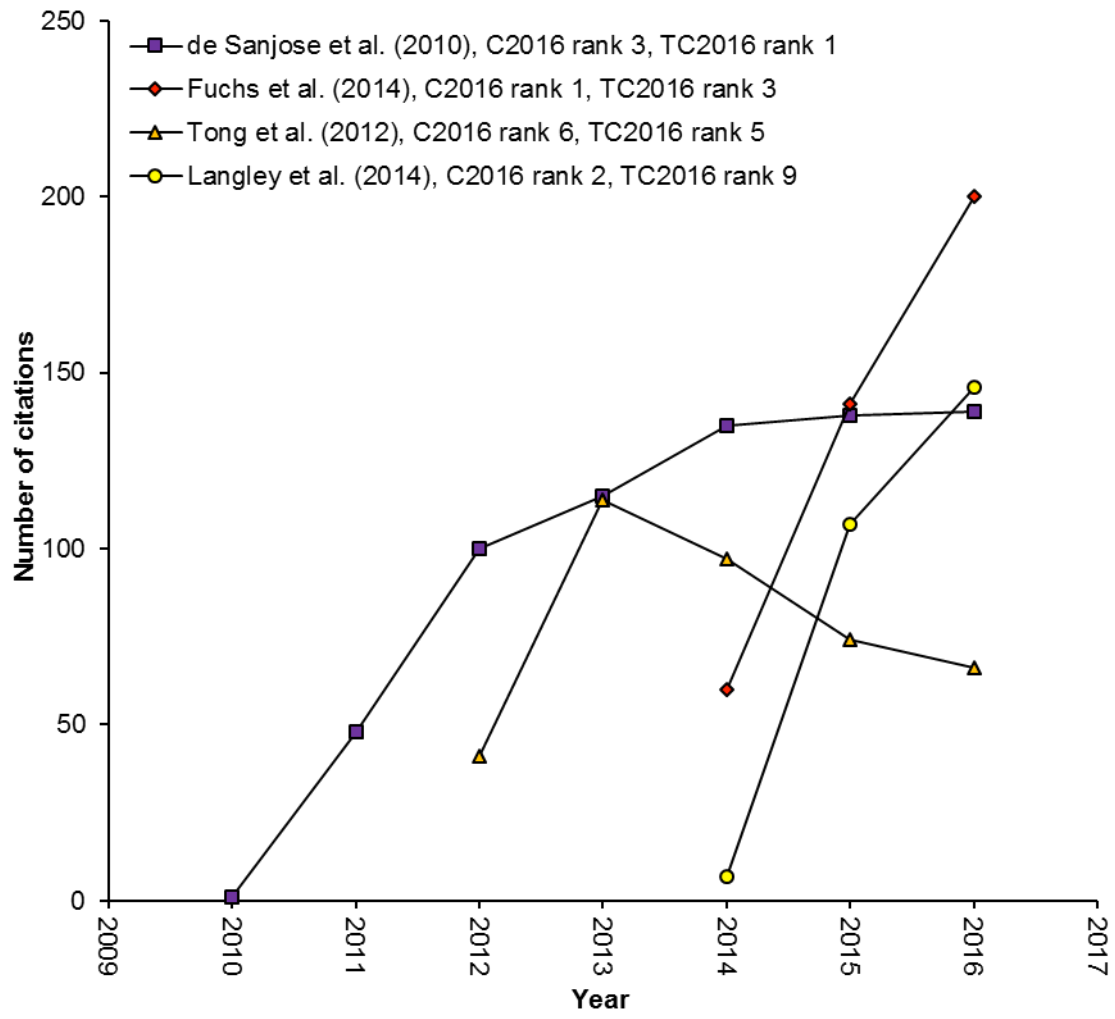


Figure 13. Publication trends for the top six institutions ($TP > 50$).

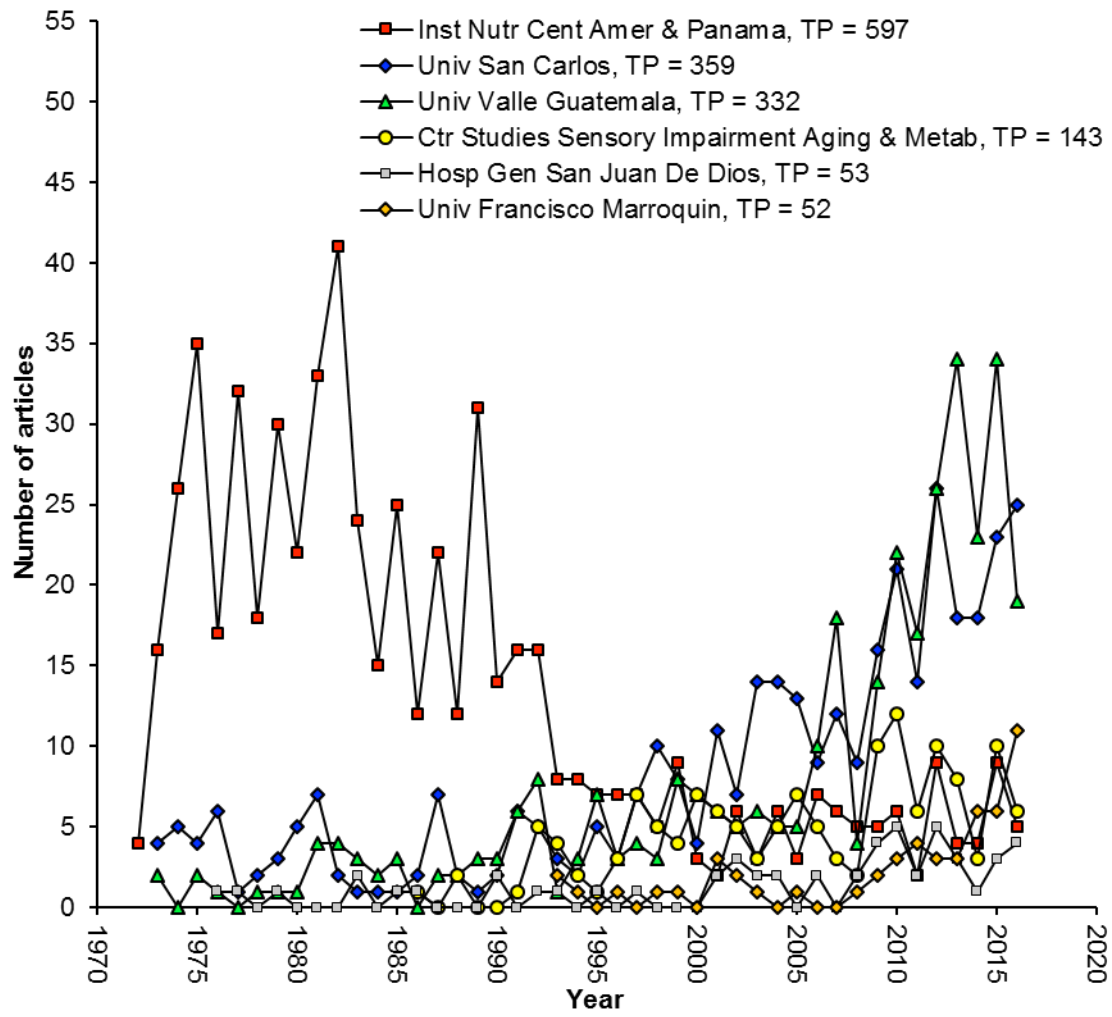


Figure 14. Historical number of article patterns for Guatemala, by the top five Web of Science category.

