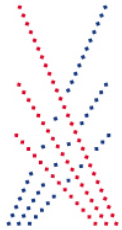

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Technology, Innovation and Sustainability in the Amazon Region: A Systematic Literature Review

Flavio Hourneaux Jr.; Cristiana Lara-Cunha; Gleriani Ferreira; Patrícia Taeko Kaetsu; Ticiana De Vincenzi.

Abstract: The development of Technology and Innovation (T&I) presents a significant relevance in poverty or isolated areas such as the Amazonian territory due to its potential to boost socio-economic development. Therefore, this study aims to bridge the literature on T&I and the sustainability perspective regarding the Amazon region. By using the Systematic Literature Review (SLR) method, we analyse a final sample of 172 papers published in 118 journals from 1992 to 2018. The bibliometric analysis covers the year and journals distribution and the most cited articles in the data analysis. Through the content analysis, we identify the main aspects of Technology and Innovation for Sustainability (T&IforS) as being types of innovation, external drivers and innovation barriers. The main findings include the identification of (a) the main themes of T&IforS studies, (b) the trends in T&IforS research, and (c) a T&IforS studies map. As a limitation, this study embraces a broad spectrum of the literature subjects. Consequently, it was possible to offer only a general overview of these subjects. At the same time, this wide-ranging and intentional approach leads to an integrative picture of T&I in a complex phenomenon as the sustainability for the Amazon region.

Keywords: Technology & Innovation; Sustainability; Amazon region; Systematic Literature Review

1. Introduction

Technology and Innovation (T&I) is an essential aspect for addressing many of society needs. T&I can promote economic growth (Schumpeter 2002; Audretsch, Bozeman & Combs 2002; Freeman & Soete 2008) and it may be a changing key in the economic, political, technological, social and cultural environment (Utterback 1971).

In this sense, T&I represents a wide-ranging concept which includes both, practical and theoretical approaches (Dosi 1982). For instance, the different types of innovation, either technical (Garcia & Calantone 2002; Damanpour 1991) or administrative (Damanpour 1991; OECD/Eurostat 2018) can be applied to numerous disciplines.

The concept of sustainability is critical, as well. Since the beginning, when definition of Sustainable Development was spread worldwide as the "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, p. 43), until the launch of the 2030 Agenda and the Sustainable Development Goals (UN 2015), the sustainability is a key issue in several fields of knowledge that can be also included in T&I debate. Technology and innovation are essential for sustainability as they support the community (Seyfang & Smith 2007), civil society and NGOs development (Tang, Karhu & Hamalainen 2011), it is also essential for firm's competitiveness (Porter & Van der Linde 1995; Nidumolu, Prahalad & Rangaswami 2009) and works as a driver to achieve social and ecological aims (Boons et al. 2013),

Recently, T&I and Sustainability can be found together in a diversity of terms. Some examples are the Sustainability-Oriented Innovation (SOI) (Adams et al. 2016), Eco-innovation (Kemp & Pearson 2008), Environmental Innovation (Kemp & Arundel 1998), Green Information Technology (Salles et al. 2016) and Innovation for Sustainability (Evans et al. 2017). It demonstrates that concepts of T&I and Sustainability together are a current trend.

In this study, we have used as a basic construct of Technology and Innovation for Sustainability (T&IforS) is analysed in a broader perspective. According to this idea, T&IforS encompass the technical (product/service or process), administrative or methodological development of technologies and present the sustainability as a requirement to tackle the market and society's demands and address the development of public policies.

There is special attention on the T&IforS in the Amazon area for its relevance in global sustainability. The region encompasses 7.8 million km^2, 1,497 municipalities of nine countries: Bolivia, Brazil, Colombia, Ecuador, Guyana, French Guiana, Peru and Suriname (RAISG 2012). It has the world's largest rainforest accounting for 1/3 of the world's humid tropical rainforests and greatest biodiversity on Earth (IBGE 2011). The area comprises 1/5 of the planet's freshwater and 25,000km of navigable rivers through 6,900,000km^2 (FAO 2012). Despite its rich ecosystem, the region registers very low Human Development Indexes among the municipalities (PNUD 2013).

The challenge of balancing economic growth, social development and environmental preservation has been presented in several studies (ABC 2008; Becker 2010). The area encompasses complex issues related to the inter-relation of themes as Biodiversity (e.g. Walker, Moran & Anselin 2000); Community (e.g. Espinosa & Duque 2018; Athayde et al. 2017); Energy (e.g. Bicalho, Bessou & Pacca 2016); Farming & Fishery (e.g. Bogaerts et al. 2017; Walker, Moran & Anselin 2000; Becker 2004); Forestry (e.g. Hayes & Rajão 2011); Health & Medicine (e.g. Siqueira et al. 2016); Mining (e.g. Massaro & de Theije 2018); Public Policy & Government (e.g. Pedro Filho et al. 2017); Tourism (e.g. Gabriel et al. 2016); and Water Resources (e.g. Hagenlocher et al. 2018). Therefore, T&I has a crucial role in this scenario: "[…] only science, technology and innovation can show the way of how to use natural heritage without destroying it" (ABC 2008, p.11). From this perspective, two research questions arise:

(RQ1) How is T&I linked to Sustainability in the context of the Amazon area? and

(RQ2) What are the theoretical concepts on T&I that underpin studies on sustainability in the Amazon context?

To answer these questions, this study aims to bridge the literature on T&I and the sustainability perspective regarding the Amazon region. We performed a systematic literature review (SLR), applying the techniques of bibliometric and content analysis. In management literature, SLR has been disseminated as a useful methodology to manage the diversity of knowledge for a specific academic inquiry (e.g. Tranfield, Denyer & Smart 2003) and can be used separately in T&I (e.g. Valladares, de Vasconcellos & Di Serio 2014) and sustainability (e.g. Searcy 2012) or together (e.g. Klewitz & Hansen 2014).

This paper structure has four mains sections. After this introduction, we present the theoretical foundations for guiding this study. Afterwards, we describe the methodological aspects of conducting the SRL. Then present the results and analyses. Finally, we provide the conclusions, a research agenda, our recommendations and the final remarks.

2. Theoretical framework

It is very important to understand the context in which innovations and technology happen, especially in remote regions like Amazon. Many factors influence them, remarkably barriers regarding the geographic scope and vastness of the area. However, some factors can also work as a driver to innovation and technology, as the huge biodiversity, revealing the importance of the region. Therefore, the next sessions will discuss aspects of technology and innovation to show the potential of the region studied.

2.1. Technology and Innovation

There are many pieces of evidence, authors and researches supporting that innovations, as well as scientific and technological advances, promote economic growth (Schumpeter 2002; Audretsch et al. 2002; Nelson 2006; Freeman & Soete 2008). On the other hand, the process of developing innovations and new technologies are embedded in the economic, political, technological, social and cultural environment (Utterback 1971).

Technology can be defined as "a set of pieces of knowledge, both directly 'practical' (related to concrete problems and devices) and 'theoretical' (but practically, applicable although not necessarily already applied), know-how, methods, procedures, experience of successes and failures and also, of course, physical devices and equipment." (Dosi 1982, p. 151-152). Audretsch et al. (2002, p. 156) specify technology as "the application of new knowledge learned through science to some practical problem". Nelson (2007, p.5) has "a broad view of what technologies are, defining the term as encompassing the wide range of productive techniques for meeting needs that humankind has developed over the years".

2.2. Technical innovation

Technological development is intrinsically linked to an innovative process, which can be understood as "new technology adopted from others so as to increase agricultural yield, or (…) the actual development of a new technology to do the same. When the process is completed, and when the innovation is put into use, there will be an increase in productivity, and possibly, substitution of capital for labour" (Audretsch et al. 2002, p. 157).

"An innovation implies a technologically new product/process or a product/process having undergone a significant technological improvement. Consequently, minor modifications to products and processes (e.g. improvement of the product design or package) are not considered as innovations" according to Becheikh, Landry and Amara (2006, p.645). Also, the authors state that it needs to be implemented, so it can be considered an innovation.

According to the Oslo Manual, innovation, in a general sense, is: "…a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into

use by the unit (process)" (OECD/Eurostat 2018, p. 20). Also, according to the same publication, "this definition uses the generic term 'unit' to describe the actor responsible for innovations. It refers to any institutional unit in any sector, including households and their individual members" (OECD/Eurostat 2018, p. 20). By using this term, the purpose was to comprise the four economic sectors (Business, Government, Non-profits serving households, and Households).

"Innovation is a dynamic and pervasive activity that occurs in all sectors of an economy; it is not the sole prerogative of the Business enterprise sector. Other types of organisations, as well as individuals, frequently make changes to products or processes and produce, collect, and distribute new knowledge of relevance to innovation" (OECD/Eurostat 2018, p. 44).

According to this definition, the Oslo Manual encompasses innovations that do not necessarily come from the organisational world. This type of innovation has been called social, community, bottom-up or grassroots innovations (Tang, Karhu & Hamalainen 2011). In studying technology perspectives and innovative scenarios applied in the Amazon area, this type and other similar initiatives are considered to foster development and sustainability in remote regions.

Grassroots innovations are "networks of activists and organisations generating novel bottom-up solutions for sustainable development" (Seyfang & Smith 2007, p. 585). Also, "Grassroots and commercial innovations do not exclude each other but rather have complementary strengths and impediments and may dominate different phases of the innovation journey, up-scaling and diffusion of new environmental technologies and services" (Ornetzeder & Rohracher 2013, p. 865).

2.3. Innovation type

Regarding innovation types, several authors consider products or processes innovations as technological, differentiating them from non-technological innovations (such as organisational, marketing, strategic, and others). "Technological innovations are those innovations that embody inventions from the industrial arts, engineering, applied sciences, and/or pure sciences" (Garcia & Calantone 2002, p. 112). Technological innovation is seen as including product and process innovation (Mothe & Nguyen-Thi 2010, p. 314). "We are interested in technological innovations related to products and processes" (Becheikh, Landry & Amara 2006, p.645). "Technical innovations pertain to products, services, and production process technology" (Damanpour 1991, p. 560).

Although both are technical, product and process innovations are intrinsically different. "Product innovations can involve two generic types of products: goods and services" (OECD/Eurostat 2018, p. 71). "A product innovation is a new or improved good or service that differs significantly from the firm's previous goods or services, and that has been introduced on the market" (OECD/Eurostat 2018, p. 70). Instead, process innovations are "new or improved business process for one or more business functions that differ significantly from the firm's previous business processes, and that has been brought into use in the firm" (OECD/Eurostat 2018, p. 72). Also, it states that "a business process innovation can involve improvements to one or more aspects of a single business function or combinations of different business functions".

Damanpour (1991) states that it is important to differentiate administrative (non-technical) and technical innovations (products and processes) since they relate to distinct entities: organisational structure and technology. "Administrative innovations involve organisational structure and administrative processes" (Damanpour 1991, p. 560).

Organisational innovations are "subsumed under one type of business process (administration and management)" (OECD/Eurostat 2018, p. 75). This function covers: "strategic and general business management (cross-functional decision-making), including organising work responsibilities; corporate governance (legal, planning and public relations); accounting, bookkeeping, auditing, payments and other financial or insurance activities; human resources management (training and education, staff recruitment, workplace organisation, provision of

temporary personnel, payroll management, health and medical support); procurement; managing external relationships with suppliers, alliances, etc." (OECD/Eurostat 2018, p. 73).

Innovation regards the improvement or the development of something new and valuable, and "this can also be applied to a research method or system" (Fields 2015, p. 62). Methodological innovation is defined as "novel research practice outside of the mainstream – mainstream diffusion is not taken as a key marker of methodological innovation. From this perspective, the transfer of concepts and practices across contexts and disciplines is central to how methods are adapted and adopted in innovative ways and thus a significant dimension of methodological innovation" (Jewitt, Xambo & Price 2017, p. 107). "Innovative research practices as those which involve technological innovation, cross disciplinary boundaries and/or extend existing methodologies and methods" (Xenitidou & Gilbert 2009, p. 7)

2.4. External factors regarding technology, innovation and sustainability

Understanding the context in which innovations happen is necessary for studying technology perspectives in remote regions. External factors can influence the types of innovation, challenges, opportunities, activities, capabilities and outcomes (OECD/Eurostat 2018). "Depending on the context, an external factor can act as a driver of innovation or a barrier to innovation" (OECD/Eurostat 2018, p. 160). Also, "The external factors that can drive innovation can be grouped into three main categories: (i) the firm's market environment; (ii) public policies including regulations; and (iii) the social environment" (OECD/Eurostat 2018, p. 160).

The market environment encompasses domestic customers, international markets, suppliers, competitors, among others. Public policies cover regulations, taxation and government support for innovation, among others. Social environment includes consumer responsiveness to innovation, and level of trust among economic actors, among others (OECD/Eurostat 2018).

"External barriers to innovation emerge when the firm interacts with other firms, agents or institutions in the innovation system" (Hölzl & Janger 2013, p. 1452). Sandberg and Aarikka-Stenroos (2014) classify external barriers into two: resistance or lack of support from specific actors, for instance the customer resistance, unsupportive government, paucity of external finance, or rivalry; and restrictive macro environment as found in the undeveloped network and ecosystem, technological turbulence, inappropriate infrastructure, or restrictive local culture.

These references provided the base to categorise the innovations. Table 1 displays the categories used in the analyses to classify innovation types, technical innovations, and external factors to innovation and sustainability.

Table 1. **T&I categories**

Aspect	Categories	Definition	Source
Innovation type	Technical	Products, services, and production process innovations comprising new or improved technologies from the industrial field, informatics, engineering, and sciences.	Garcia, Calantone (2002) Damanpour (1991)
	Administrative	Innovations encompassing organisational structure and administrative processes such as strategic and general business management, corporate governance, human resources management and procurement.	Damanpour (1991) OECD/Eurostat (2018)
	Research method	Research methods using technological innovations, crossing disciplinary frontiers or mixing and applying existing methodologies in new and different ways.	Xenitidou and Gilbert (2009)
Technical innovation	Product/service	New or significantly improved goods or services.	OECD/Eurostat (2018)
	Process	Improvements to business functions related to the production of goods or services.	OECD/Eurostat (2018)
External factors to innovation and sustainability	Public policies	Regulations, policies, and government programs	OECD/Eurostat (2018)
	Marke/society	Market forces and pressures from consumers, competitors, civil society, NGOs, class entities and communities.	OECD/Eurostat (2018)

Source: Research data

3. Methodology

The Systematica Review of the Literature (SLR) is important for researchers while helping to organise and prioritise all the most relevant data (Petticrew & Roberts 2006). This method of research can be useful when handling a "large bodies of information" (Petticrew & Roberts 2006, p. 2) and where researchers struggle with a great volume of data (Tranfield et al. 2003). Moreover, SLR is appropriate when mapping areas where there are both great uncertainty and the need for new studies (Petticrew & Roberts 2006).

A SLR limits the bias when trying to identify, evaluate and synthesise all the relevant studies in a particular area (Petticrew & Roberts 2006). Likewise, according to the authors, SLR aspires to answer a specific research question, instead of simply resuming "all there is to know" about a specific field or issue (Petticrew & Roberts 2006, p. 10).

The search was conducted on the ISI Web of Knowledge/Web of Science (WoS) database. Three languages were searched: English, Spanish and Portuguese. All the years were selected (1900-2018) as the study was conducted between December of 2018 and January of 2019.

As recommended by Tranfield et al (2003), we followed the three stages of a systematic review. The review first was planned, then conducted and finally reported and disseminated (Tranfield et al. 2003). Table 2 summarises the stages followed in our research.

Table 2. **Steps of the systematic literature review conducted.**

1st stage planning the review	**2nd stage conducting the review**	**3rd stage reporting and disseminating**
− Literature search on innovation and management in the Amazon region, done by trial-and-error; − Suggestion of the research questions; − Definition of the criteria used for the filters and selection of the samples; − Development of the 'review protocol'.	− Identification of research, by choosing the words used; − Selection of the studies by definition of the initial papers sample, with 316 studies; − Usage of the filters and selection of the reading sample, with 255 studies; − Reading and data analysis, conducted in rounds by pairs of researchers, followed by the tiebreaker third researcher; − Selection of the final sample, after consideration of at least three researchers, consisting of 172 studies; − Elaboration of the tables, graphics and figures to exemplify the findings and conclusions of the analysis.	− Initial draft of the paper, simultaneous with the rounds of the researchers; − Elaboration of the report co-occurring with the data analysis.

Source: Adapted from Tranfield et al (2003).

In the first stage, tests and combination of words were tried. This stage is known as trial-and-error, aiming to understand the need and viability of the study (Morioka & Carvalho 2016). This stage is relevant to draw an initial version of the research questions and define the criteria used for the filters on the studied sample. Then the 'development of a review protocol' (Tranfield et al. 2003) was done to offer a protocol less biased than the narrative reviews.

The review *per se* was done during the second stage through the data collection as presented by Tranfield et al (2003). The following filters were applied in the WoS database: (1) in the topic: amazon* AND sustainab* AND technol*; (2) in the topic: amazon* AND sustainab* AND innov*. Those two searches were also done in the Spanish language, as well as in Portuguese. The symbol (*) embodies a function of the database that includes variations of the searched term.

The first round of searches exhibited 316 matches. Then, using the filter 'document types' provided by the database, we selected the topics 'Article, Review, Editorial and Other', resulting in 255 matches. Following Morioka and Carvalho (2016), we first read the title and abstract of the papers to exclude the ones with no adherence to the search and those that do not present the full paper available. This step was done by two different researchers and, in case of disagreement, a tiebreaker third researcher to take the final decision. Finally, the reading of the entire papers was done, ending up with a refined final sample of 172 papers.

Once the second round of reading was concluded, the next step represented the content data analysis and the classification of the papers. The spreadsheet presented the following divisions: Author, Title, DOI, Abstracts in English, Spanish and Portuguese, Year, Journal, Type of Innovation, Technical Innovation, External Factors to Innovation and Sustainability, Combination of Themes and T&I, Region, Country of Authors' Institution, Themes and Keywords & Figures. The classification supported the findings and conclusion of the analysis.

Finally, the third stage of research, according to Tranfield et al (2003), is represented by the reporting and dissemination, analysis of collected data, study writing and results and discussions.

4. Results

4.1. Bibliometric analysis

The Amazon studies joined a huge variety of researches developed in the region. The criteria for paper's selection represented by sustainability and technology & innovation can be found in different disciplines and sciences covering basic and applied researches. Therefore, the

range of analysed articles comprised various sorts of themes, from specific endangered species of animals or plants to broader global issues like climate change.

In order to address this multidisciplinary challenge of the systematic review, the initial key tasks involve summarising the results of the studies, describing the most important characteristics of the included studies (population, methods, details of interventions, and their outcomes, if relevant). Petticrew and Roberts (2006) recommend breaking down the analysis process into three steps: (i) organising the description of the studies into logical categories, (ii) analysing the findings within each of the categories, and (iii) synthesising the findings across all included studies. The following sections are ordered according to this division and the analysis mixed automatic and manual data using different options of available online and software tools.

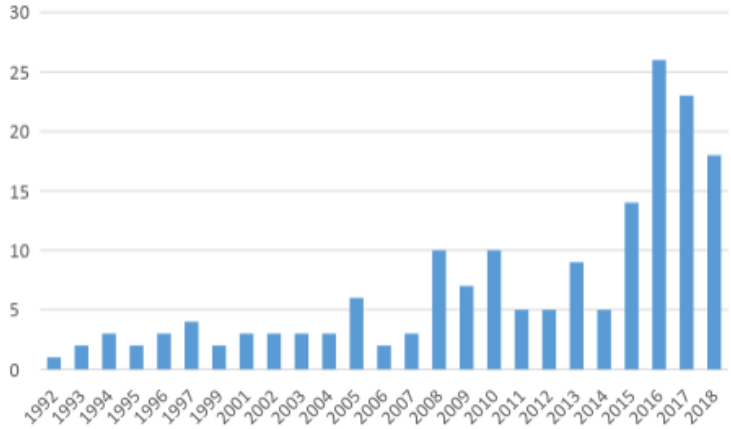
4.1.1. Descriptive statistics

Descriptive statistics of the sample refers to the analysis of the frequency of the publications. The criteria considered the publication's timeline, the distribution among journals and the regions that were the target of the studies.

Studies evolution: publication's timeline

Despite the use of all years of the database (1900-2018), Figure 1 of the publication's timetable demonstrates that the first paper in our sample was published in 1992. This year was a milestone for the sustainable development theme, as the Earth Summit – Rio 92 took place. This finding shows the significance of the event as there was an emergent production of sustainability studies, particularly in the Amazon.

Figure 1 – Publication's timetable (number of articles per year)



Source: Research data

Figure 1 also shows the development of studies and a rising growth rate starting in 2015. During this year, the Agenda 2030 proposed by the United Nations (UN) was adopted by many global leaders, and the 17 Sustainable Development Goals (SDG) were launched. The evolution of the published papers as well as the increase of the number of papers in the next year (2016) shows the possible impact of the SDGs on the academic field.

Distribution among journals

The sample presented the publications spread among a great number of journals. All the articles were published by 118 different journals, and only one (Agroforestry Systems) had more than 5% of the publications. Table 3 shows the 12 journals with the highest number of publications. The threshold criteria were the presence of three papers or more.

Table 3. **Journals with the highest number of publications.**

Journal	Publications	% of the total	Cumulative
Agroforestry Systems	9	5,2%	5,2%
Acta Amazonica	4	2,3%	7,6%
Ecology and Society	4	2,3%	9,9%
Energy Policy	4	2,3%	12,2%
Land Use Policy	4	2,3%	14,5%
Ecological Economics	3	1,7%	16,3%
Environmental Conservation	3	1,7%	18,0%
Estudos Avançados	3	1,7%	19,8%
Forest Ecology And Management	3	1,7%	21,5%
Journal of Cleaner Production	3	1,7%	23,3%
Novos Cadernos NAEA	3	1,7%	25,0%
Renewable & Sustainable Energy Reviews	3	1,7%	26,7%

Source: Research data

Geographic and spatial scope: Amazon area

The geographical scope represents the main boundary of this research and this category analyses the spatial focus of the investigated sample. From the 172 articles in the sample, Table 4 presents the frequency of these target regions. The data was investigated to identify the scope of the study, analysing the region where it took place. Although the Amazon region spreads over nine countries, the majority had the Brazilian Amazon as the target of their study representing 122 papers. This result roughly reflects the spatial distribution of the Amazon Biome as approximately 60% of the rainforest is located in Brazil. The 38 articles of Non-Brazilian Amazon articles were developed especially in countries such as Peru, Colombia, Bolivia and Venezuela. The seven Multi-countries Amazon occurrences included the studies done in more than one country of Amazon area and the Amazon and Other Region considered the investigations that focused on the Amazon and other areas worldwide.

Table 4. **Regions studied in the publications**

Journal	Publications	% of the total
Brazilian Amazon	122	70,9%
Non-Brazilian Amazon	38	22,1%
Multi-Countries Amazon	7	4,1%
Amazon and Other Regions	5	2,9%
Total	172	100,0%

Source: Research data

To gather this data, the information regarding the origin of the institution where all the authors belong was searched and held in the spreadsheet. Therefore, Brazil comprises 64% of the total territory of the Amazon and represents the unit of analysis of 70.9% of the studies. Brazil is the country with the highest volume of publications (57.56%), of which 25% was carried out in partnership with other countries. The USA came in second place with 19.77% of the total number of studies which 12.79% were carried out exclusively by universities and American institutions.

Other countries that hold 35.8% of the Amazonian territory account for only 11.63% of the studies, demonstrating the predominance of exogenous researchers.

4.2. Content analysis

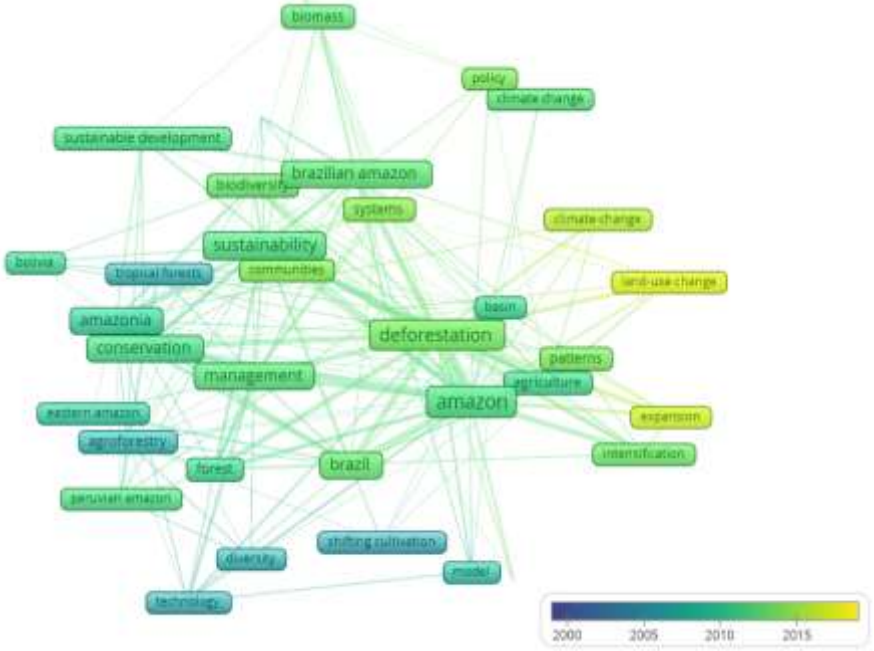
4.2.1. Logical categories

The logical categories of selection offer a general overview of this sample. These categories correspond to the criteria of the paper's selection previously applied in the WoS database and following classification of the articles. The criteria considered the co-occurrence of the keywords, the main themes covered by the papers and the categories of T&IforS identified in the sample.

Theoretical concepts of investigations

The overlay visualisation was created based on bibliographic data and presented the minimum of five co-occurrence of keywords which weight is fractionated among all appearance displayed in the same paper. The results showed 37 terms connected according to the relations among the keywords in the same article and the colours represent the publication's timetable of the keywords. Figure 2 presents the results of the keywords co-occurrences.

Figure 2**. Keywords co-occurrence per year**



Source: Research data

4.2.2. Research themes by T&IforS categories

The paper's sample was divided into 11 categories according to the thematic areas where the innovations took place. Additionally, the Innovation Classification data was crossed with the thematic areas to offer an overview of the main investigation's interests and innovations drivers. Table 5 shows the studies and themes.

We identify the most remarkable aspects of the sample, such as the themes addressed by T&I through a sustainability perspective. The top three "Farming & Fishery" (30.8%), "Forestry" (18%) and "Biodiversity" (16.9%) correspond to 2/3 of the studies reflecting their relevance to the Amazon context. Accordingly, there is a concentration of researches related to the external factors or drivers for T&IforS mainly connected to "Farming & Fishery" and "Forestry". The types of innovation analysis show that most studies address the "Technical process" and "Research".

Table 5. **Themes x T&IforS categories**

CATEGORIES / THEMES			Biodiversity	Community	Energy	Farming & Fishery	Forestry	Health & Medicine	Mining	Public Policy & Government	Tourism	Water Resources	Other	TOTAL
External Factors	Market / Society		2,9%	1,7%	0,6%	9,3%	1,2%	0,0%	0,6%	0,6%	0,6%	0,0%	0,6%	**18,0%**
	Public Policies		1,7%	0,6%	4,1%	2,9%	3,5%	1,2%	0,0%	4,1%	0,0%	0,0%	0,0%	**18,0%**
	Market / Society & Public Policies		3,5%	2,9%	2,3%	6,4%	7,0%	0,0%	0,0%	1,7%	0,0%	0,6%	0,6%	**25,0%**
Innovation Types	Administrative		0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,6%	0,0%	0,0%	**0,6%**
	Technical	Process	4,1%	0,6%	1,2%	8,7%	1,2%	0,0%	0,0%	0,0%	0,0%	0,6%	1,2%	**17,4%**
		Product / Service	2,3%	0,0%	0,0%	0,0%	0,6%	0,0%	0,0%	0,0%	0,0%	1,2%	0,0%	**4,1%**
		Process & Product / Service	0,0%	0,0%	0,0%	0,6%	0,6%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	**1,2%**
	Technical & Administrative	Process	0,0%	0,0%	0,0%	0,6%	0,6%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	**1,2%**
		Product / Service	0,0%	0,6%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	**0,6%**
	Research / Methodology		2,3%	4,1%	0,6%	2,3%	3,5%	0,0%	0,0%	0,0%	0,0%	0,6%	0,6%	**14,0%**
TOTAL %			**16,9%**	**10,5%**	**8,7%**	**30,8%**	**18,0%**	**1,2%**	**0,6%**	**6,4%**	**1,2%**	**2,9%**	**2,9%**	**100,0%**
TOTAL ARTICLES			**29**	**18**	**15**	**53**	**31**	**2**	**1**	**11**	**2**	**5**	**5**	**172**

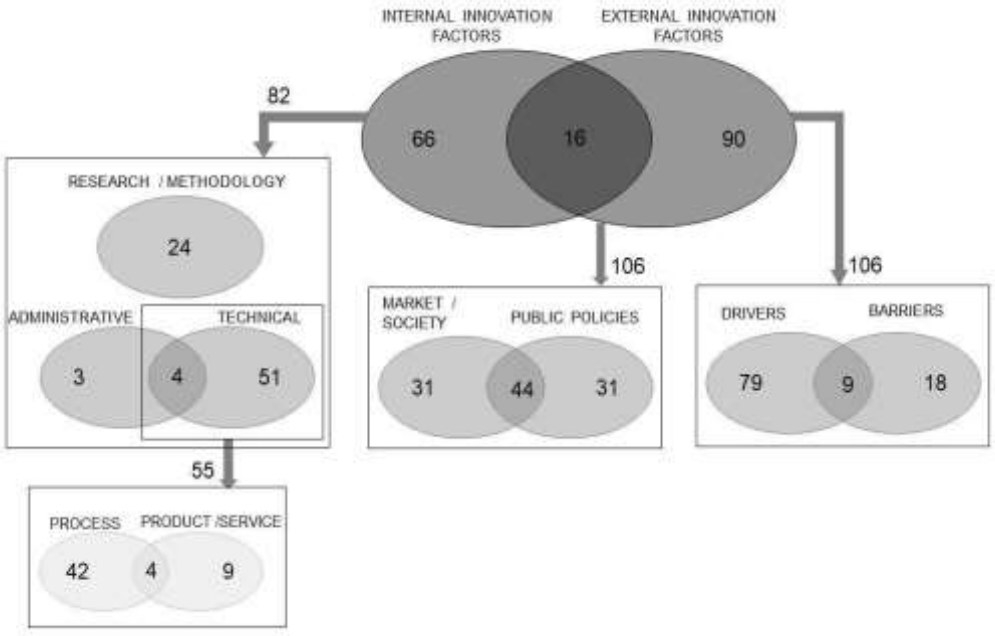
Source: Research data

4.2.3. Summary of the studies' analyses

Figure 3 summarizes the classification of all the studies into the categories established in this study that are detailed in section 5 – Discussion. This figure shows the existing division in the studies sample: 38.4% of the papers address only one type of innovation, and 52.3% discuss exclusively external factors. Articles mentioning both issues and presenting an integrated vision on T&IforS account for merely 9.3% of the base.

In our sample, no article classified the innovations according to type, innovative process (collaborative or not) and degree of novelty (radical or incremental). The descriptions in the papers through a deductive process demonstrates that the innovations are all incremental and many innovations have been developed in a collaborative process with institutions of different natures, such as universities, NGOs, research institutes (e.g. EMBRAPA – Brazilian Agricultural Research Corporation) and others. However, these are inferences as no categorisation was provided by authors.

Figure 3**. Sample classification according to the categories of analysis**



Source: Research data

5. Discussion.

5.1. Types of innovation

As we can see in Figure 3, a significant number of papers (82) addressed some type of innovation: the majority focus only on technical innovations (51); few are only about administrative innovations (3) or about technical and administrative (4) innovations; and 24 articles refer to research method innovations.

The systematic review revealed the popularity of process innovations: most of the articles that mentioned **technical innovations** (55) refers to process-only innovations (42). A few (9) were about only product/service innovations, and fewer (4) were related to both process innovations and product/service innovations.

The findings indicate that very few studies (7) refer to **administrative innovations**. The main subjects are: different forms of self-organization, new modes of interaction with others outside the community, leadership, and decision-making process (Huntington et al. 2017); new ecotourism market development (Lowman 2009); new modes of learning and knowledge transmission (Athayde et al. 2017); and innovative partnerships (Le Tourneau & Greissing 2010).

The **research method innovations** (24) are: creative mixed methods approach or merged analysis techniques (Espinosa & Duque 2018); new methodology, innovative approach, new research technology or innovative hypothesis testing (Hagenlocher et al. 2018); and crossing disciplinary boundaries (Zhang 2017). Some studies (3) are not properly about innovative methods, but rather unprecedented applications of existing methods (Larrea-Gallegos, Vazquez-Rowe & Gallice 2017).

Many different topics are addressed by the **research method innovations** articles, but the most cited are deforestation maps and forest inventory about land use and cover types (Silva-Matos et al 2018) and deforestation impacts (Aguiar et al. 2016).

5.2. Technical innovations

As we can see in Figure 3, findings indicate that the majority of technical innovations studies are about **process innovations** (46). The main subjects were process innovations aiming at sustainable agricultural intensification (Miltner & Coomes 2015), innovative integrated crop-livestock and/or agroforestry systems combining crop, livestock and/or forestry activities

(Hohnwald et al. 2015), soil-fertility improvement process (Theodoro et al. 2013), no-till agriculture, post-harvesting silvicultural and agrobiodiverse systems (Schwartz et al. 2016).

Many articles addressed improved agroforestry systems techniques to explore forest raw materials sustainably (O'Neill et al. 2001), reduced-impact logging process (Farias, Rivero & Diniz 2017), technological innovations improving quality and/or productivity in beef and dairy production (Ferreira et al. 2017), new technologies for territorial mapping and monitoring or geographic information systems (Paneque-Galvez et al. 2017) and off-grid renewable energy technologies or electricity challenges (Sánchez, Torres & Kalid 2015).

Other topics were technological innovations in small-scale gold mines (Massaro & Theije 2018), technologies for rubber vulcanization (Sarmento & Moura 2017), increasing water availability (Hunt & Leal Filho 2018), innovative structural system that uses concrete instead of wood (Carvalho et al. 2010), improvement of fishing techniques (Huntington et al. 2017) and composite materials development from natural vegetable fibers with advanced production technology (Marinelli et al. 2008).

We found four articles that do not cite existing process innovation, but basic research that can lead to innovations in soil management, agroforestry processes, biomass fuel production and safe environmental discharge (e.g. Salvadori et al. 2016).

Very few studies (13) refer to **product/service innovations**. The main innovations were: devices for sanitation and water treatment (Ribeiro, Abreu & Laporta 2018); new renewable energy sources, like biomass and biofuels (Hogarth 2017); new products made from forest raw materials (Marinelli et al. 2008); and a vessel model for scientific or non-scientific activities in the Amazon (Meliande et al. 2014).

Some of these articles do not cite existing innovations, but projects (Meliande et al. 2014) or basic research about raw materials with potential to product innovation (Reisdorff et al. 2004).

5.3. External factors as drivers and obstacles to innovation and sustainability

As we can see in Figure 3, considering all 172 articles, the most mentioned subject was external factors as drivers and obstacles to innovation and sustainability (106), albeit 90 of those are only on this topic, and 16 are about technical and/or administrative innovations in which external factors contributed directly to their development.

Market or society forces (31), public policies (31) and both topics (44) are the external factors addressed by the studies. Innovation and sustainability drivers were pointed out in 88 articles, while 27 mentioned barriers: 79 articles are just about drivers, 18 just about barriers and 9 cite both drivers and obstacles (Tejada et al. 2016).

Regarding innovation and sustainability **drivers (88)**, the most mentioned **public policies drivers** were, as follows.

Brazilian's forest governance reforms and government's commitments to decrease deforestation restoring degraded pastures through agricultural intensification (Gil, Siebold & Berger 2015), community-managed reserves, conservation units and Brazil's national system of protected areas including extractive and sustainable development reserves (Teisserenc & Guilhem 2016).

Brazilian energy planning, amazon hydropower projects and rural electrification program (Gomez & Silveira 2015), Brazilian national biodiesel production program (Lima, Skutsch & Costa 2011), Brazilian health care program and social protection services for indigenous people (Shankland et al. 2013), Brazilian Forest Conservation Grant program (Viana 2008), REDD+ implementation in the Brazilian Amazon (Gebara & Agrawal 2017), Brazilian Rural Environmental Registry (CAR) impacts (Roitman et al. 2018), Brazilian's government plan aiming at sustainable growth, employment and social inclusion (Costa 2005).

The state of Amazonas plans to turn its capital Manaus into a green global city (Schindler & Kanai 2018); the state of Mato Grosso Produce, Conserve and Include Strategy (PCI) plan to reduce greenhouse gas emissions (Milhorance & Bursztyn 2018), Brazilian Sustainable Amazon

Region Plan (Madeira 2014), environmental service market based on reforestation credits under Brazilian legislation (Schroth & Mota 2013), Brazilian Amazon governance and geographic information systems (Hayes & Rajao 2011), Coari-Manaus natural gas pipeline impacts (Frota et al. 2010), municipal councils for sustainable rural development (Olival, Spexoto & Rodrigues 2007).

Brazil's Sustainable Palm Oil Production Program, Low-Carbon Emission Agriculture Program and GHG emission reduction target and others Brazilian's conservation laws (Oliveira, Silva & Tostes 2015), Brazilian environmental licensing law demanding conservation units in mineral exploitation (Viana et al. 2016), international science program Large Scale Biosphere-Atmosphere Experiment in Amazonia (Nobre, Lahsen, & Ometto 2008), social workers government's program (Hall 1996) and Brazil's remote-sensing programme to measure deforestation (Downton 1995), Ecuador's Amazon lowlands project to improve agroforestry practices and regenerate deforested areas (Ramirez, Sere & Uquillas 1992) and Peruvian National Forest Conservation Program for Climate Change Mitigation (Boerner, Wunder & Giudice 2016).

The most mentioned **market or society drivers** were: market or social pressures from consumers, small farmers groups, non-governmental organisations, indigenous and local communities driving to the adoption of sustainable forest management practices, agroforestry, intercropping, forest resources, farming agroecological methods and land use practices that increase sustainability and productivity in agricultural practices (Pinton 2003).

Markets forces developing commercial fishery/ fish and prawn markets (De Jesus & Kohler 2004), sustainable expansion of biofuel production (Lossau et al. 2015), Brazil nuts (Freitas-Silva & Venancio 2011), ecotourism (Lowman 2009) and logging (Holmes et al. 2002).

Other drivers to innovation and sustainability: local entrepreneurs citizens and riverine communities engaged in conservation of natural resources and long-term sustainability in the Amazon region (Pedro Filho et al. 2017), firearm use in indigenous hunting (Levi et al. 2009), biomass potential for electricity supply in riverside communities (Miranda et al. 2008), miners cooperative developing sustainable mining methods (Massaro & Theije 2018).

There are 27 studies about innovation and sustainability **obstacles** raised by public policies, market or society. The subjects affected by public policies barriers (4) were land use and deforestation (Tejada et al. 2016), disease control (Siqueira et al. 2016), wildlife consumption market (Parry, Barlow & Pereira 2014) and agroforestry food products (Lima et al. 2013).

The studies that mentioned market or society barriers (10) are about agroforestry challenges (Horn, Gilmore & Endress 2012), efforts to protect forest resources and mitigate pollution (Vickers 1994), barriers to the adoption of sustainable practices (Smith et al. 1996), market forces that stimulate rather than slow deforestation (Vadez et al. 2008), agricultural intensification (Garland, Aramburú & Burneo 2017), productivity and sustainable hurdles in agriculture (Oliveira, Santana & Homma 2013), pasture and herd limitations in sustainable management (Sarmento et al. 2010).

The issues aimed by articles citing both public policies and markets or society barriers (13) are agriculture, livestock and agroforestry systems (Follis & Nair 1994), land use and environmental services (Fearnside 1997), forest industries (Ros-Tonen 2007), deforestation (Hecht 2005), forest monitoring (Amaral & D'Alge 2009), household water treatment (Rothstein et al. 2015), pesticides overuse (Waichman et al. 2002).

6. Research Agenda

In this section, we explore the two research goals informed previously in the introduction, referring to future developments.

The studies in the Amazon region aiming its sustainability through the T&I development face multidisciplinary challenges of micro and macro-levels. In the micro-level, the great number

of case studies in our sample offered an overview of organisations investigating the biodiversity field and production issues. In a macro-level, the papers reflected the territorial complexity of studying the region. There was a focus on geosciences to analyse the spatial tools and methods that support the territorial planning and management of public and private organisations.

The Amazon Biome exceeds the political division of countries; however, our sample mainly focused in the Brazilian Amazon and exhibited a relevant non-integration in the investigations. Different institutions using and producing isolated information, generate resources and knowledge dispersion. Moreover, the analyses demonstrate the gap in studies related to the integration of data and indicators which are relevant for monitoring the Amazon as a whole and as a consequence, improving the T&I development.

The non-integration of information sources also represent a constraint to the public policies development. The Amazonian territorial planning affects several areas of public action, which are closely interrelated to the private and/or the third sectors. Thus, the demand for an integrated approach also includes investigating the multi-stakeholder partnerships that mobilise and share knowledge, expertise, technology and financial resources to achieve the Amazon development. Broadly, there is a demand for studies concerning the innovation ecosystem in the Amazon.

Once the UN provides the SDGs global indicators framework, it embodies a reference to produce standardised data and represents a potential research area. This paper sample though presented only one article directly mentioning the SDGs. Indirectly, most analysed papers could be related to goals 15 – Life on Land, 13 – Climate Action, 2 – Zero Hunger (and sustainable agriculture), and 7 – Affordable and Clean Energy. The development of studies associated to the goal 9 – Industry, Innovation and Infrastructure, would drive the investigation to broad topics such as resilient infrastructures, inclusive and sustainable industrialisation and innovation promotion (the A/RES/70/1 document) (UN 2015). These themes would fulfil the aim of this research and involve the technological perspectives and innovative scenarios in the Amazon.

Contemporary discussions on sustainability in Amazon embrace global problems when addressing matters such as climate changes, global supply chains, biogenetic resources and intellectual property, for instance. Therefore, there is a potential study agenda focused on the systemic approach that would comprise the inter-relations among the variables and their behaviour over time to display an overview of the wider scenario.

Thus, some research questions arise. The list is not exhaustive.

- How are the SDGs incorporated in T&I in the Amazon region?
- How can radical innovation contribute to sustainability in the Amazon region?
- Can innovation networks be effective in developing sustainability in T&I in the Amazon region?
- How T&IforS influences public policy in the Amazon region?
- Do financial incentives increase the development of T&IforS in the Amazon region?
- How to increase international collaboration for developing T&IforS in the Amazon region?
- Is it possible at the same time to explore new T&I opportunities and sustainably exploit existing capabilities?
- Do innovations developed collaboratively happen in an open innovation context in the Amazon region?

7. Final remarks

The systematic review presented in this article, covering the more than 25 years of research in these themes – Technology & Innovation through a sustainability perspective in the Amazon region – presented some contributions to the subject.

In terms of theoretical implications, we present the concept of T&IforS as an attempt to integrate and turn into concrete the different approaches to tackle this critical issue. The categorisation of each initiative can also be essential subsidies for understanding the research vis-à-vis the complexity of the context.

In terms of practical implications, it is possible to notice that the dispersion of the themes found in this study confirms the plurality of Amazonian wealth and suggests that research institutions and organizations such as the Organização do Tratado de Cooperação Amazônica (Amazon Cooperation Treaty Organization - OTCA) should be able to commit to the elaboration of an integrated planning of scientific, as well as the compilation of the results achieved.

Regarding the limitations of this research, we can highlight that the SLR methodology is limitation per se, as it does not permit one to extrapolate any definite conclusion from the data analysis (Petticrew & Roberts 2006). We also acknowledge the exclusion of conference papers, book references or even reports and media publications, knows as grey literature, in this study (Richard et al. 2016). Another significant limitation is the lack of analysis on the theoretical basis of the articles; this was not a choice of the authors, but a characteristic of the sample itself. Finally, we did not consider the "quality" of the publications; i.e., we have not taken into account the impact factors or rankings of the journals to be present in the sample.

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