Contributions of scientific research to regional development in the Amazonas region, northern Peru

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ABSTRACT
The relevance of scientific research to local challenges and the need to produce actionable knowledge that benefits local development have not been evaluated. This study evaluates whether scientific research focused on the Amazonas region is framed within its five regional components of the Concerted Regional Development Plan (CRDP) to achieve sustainable development. In this study, 386 scientific articles published during 1960–2021 focusing on the Amazonas region were evaluated. Although Amazonas is the third poorest region in Peru, scientific production in this region has largely increased (CAGR 2001–2021 = 16.4%). However, women and indigenous authors are underrepresented suggesting a unilateral knowledge transfer. The highest scientific contribution was reported for component 1 of the CRDP (58%), centering on topics about the conservation of biodiversity and ecosystem services. Scientific research focusing on the Amazonas region fails to fully aboard the overall sustainable components of the CRDP. Social sciences are clearly understudied. It is the role of regional institutions (government, universities, industry, non-profit, etc.) to ensure the extension of research topics covering other dimensions of scientific knowledge and social needs. Conclusively, it is pending that local policymakers take into consideration emerging disciplines that can provide an updated perspective in developmental policies in the Amazonas region.

Introduction
Economic and social development of nations rely on their ability to transform scientific and technological knowledge into new products or processes (Mormina 2019). Scientific research provides important information on a range of areas and is expected to engage constructively with other actors in society to respond to humanitarian, societal, and global challenges, including the welfare of the community and equitable distribution of income (Smith and Todaro 2015; Bell and Willmott 2019; Nielsen 2021; Cica et al. 2021). Scientific information is also valuable for policymaking and public policy decisions based on objective science (Haller and Gerrie 2007; Song 2008; More 2019). Furthermore, science is hailed as a significant basis for innovation (i.e. new technologies) that foster market success and prosperity and support global competition in a socially acceptable and sustainable way (Simon et al. 2019). However, the capacity to produce scientific and technological knowledge is highly variable globally (Mormina 2019). According to citation impact and scientific quality indicators, scientific research worldwide is dominated by China, the United Kingdom, and the United States (Erfanmanesh, Tahira, and Abrizah 2017). In recent years, Israel, Singapore, and South Korea have considerably improved their research indicators due to the implementation of active research and development (R&D) policies that include sociocultural, geostrategic, and financial factors (Jiménez 2013; Baldeón Egas, Albuja Mariño, and Rivero Padrón 2019). R&D policies have generated well-trained academic personnel, improved quality of life standards, and increased gross domestic product (GDP) (Castelblanco Gómez and Robledo Velásquez 2014). The average national R&D
expenditures of OECD countries during 2018 was 2.4% of the national budget (Nielsen 2021). In Latin America, scientific research is dominated by Chile, Brazil, and Mexico (Ocegueda et al. 2017; Forero et al. 2020), countries that reflect a direct relationship between the improvement of economic indicators and scientific production (Ynalvez and Shrum 2011).

Low and middle-income countries require (i) new ways of knowledge production and decision-making to build research capacity beyond individual training/skills building and, (ii) tools based on transdisciplinary, community-based, interactive, or participatory research approaches to involve actors outside of academia, that reflect real-world problems and create ownership of problems and solution options (Lang et al. 2012). Since development is a process of empowerment (Edwards 1989), these strategies will meet local needs and circumstances, and provide implementation of evidence-based policies (Schmalzbauer and Visbeck 2016; Salvia et al. 2019).

In Peru, although research is considered a key tool for the design of development strategies and policies, scientific production is at a concerning low (Huamani and Mayta-Tristán 2010; Moquillaza 2019). However, compared to other countries worldwide (0.06% in 2012–0.1% in 2017) and to Latin America (1.25% in 2012–1.87% in 2017), gradual and consistent growth of scientific production has been observed in recent years (CONCYTEC 2019), mainly motivated by the increase in investment of GDP in R&D (0.108% in 2014–0.127% in 2018) (Limaymanta et al. 2020; World Bank 2021). Most of the scientific production belongs to the fields of medicine (40%), agricultural sciences (18%), and biological sciences (18%) (CONCYTEC 2019). These studies have been performed mainly in the Lima region (79.2%) (CONCYTEC 2019).

In northern Peru, the Amazonas region ranks 21st (out of 24) in the national ranking of scientific production (CONCYTEC 2019). Amazonas is a remote and unexplored region where the availability of historical records and biological information are poor, especially in rural areas and indigenous communities (Réategui et al. 2018; Altea 2020; Mick et al. 2021). The pluricultural heritage of the Amazonas region is conducive to social research, while the ecological characteristics of the region involve vast biodiversity and natural resources for biological and environmental studies (Walentowski et al. 2018). Hence, the use of these resources under a technological and innovational scope, in addition to a critical mass of qualified researchers, policymakers, stakeholders, and of efficient government policies, might contribute to the development and welfare of the Amazonas region (CONCYTEC 2016a; Calderón-Vargas, Asmat-Campos, and Carretero-Gómez 2019).

The concerted regional development plan (CRDP) is a management instrument of the Peruvian State for medium- and long-term strategic planning that guides comprehensive and sustainable development in the territory. This CRDP seeks coordination between urban and rural zones and promotes synergies with the private sector and civil society at the regional level (Anderson et al. 2018; CEPLAN 2021). The CRDP is developed with the participation and collaboration of the regional government (RG) and the National Center for Strategic Planning (CEPLAN) (CEPLAN 2021). The RG formulates and approves the CRDP with municipalities and civil society. To this end, the leadership of regional governors is important to meet the immediate needs of the population and to promote the development of the territories through strategic planning (Anderson et al. 2018). On the other side, CEPLAN advises State entities (including RG) in the formulation, monitoring and evaluation of policies and strategic development plans (Gallos and Ospino 2020). Accordingly, the CRDP from the Amazonas region during 2014–2021 framed the following five development components: (i) environment and disaster risk (C1); (ii) economy, competitiveness and employment (C2), (iii) fundamental rights and dignity of people (C3); (iv) access to services social (C4); and (v) institutionalism and governance (C5) (GOREA 2014; CEPLAN 2021).

Although Amazonas is the third poorest region in Peru, it has shown accelerated progress in scientific production (SUNEDU 2017) mainly due to the increase of funding in R&D areas by national agencies and the incorporation of specialized researchers (Moquillaza 2019). Nevertheless, the relevance of such research to local challenges and the need for such research to produce actionable knowledge that benefits local development have not been evaluated. Accordingly, the present study evaluates whether scientific research by academia focused on the Amazonas region (northern Peru) is framed within the five components of the CRDP to achieve sustainable development in Amazonas region. For such purposes, indexed articles in Web of Science, SCOPUS and SciELO focused on Amazonas region are analyzed to determine publication trends (by country, year, province, strategic objective, authorship gender, and scientific contribution networks) and contribution to the five regional strategic components of the CRDP in order to provide a more comprehensive view of the role of research in the pursuit of those components.

Material and methods

Articles indexed in SciELO, Scopus and Web of Science were analyzed for this study. These databases were selected as they support a broad array of scientific
tasks across diverse knowledge domains and contain datasets for large-scale data-intensive studies (Li, Rollins, and Yan 2018). Although grey literature may record findings in niche or emerging research areas, it was not included as the study is focused on the scientific impact of academia is aimed. Therefore, only scholarly publications that passed through a formal and rigorous peer review process were selected. Articles from 1960 to 2021 involving different research areas and focusing on the Amazonas region were compiled according to Zhao, Li, and Li (2005). Briefly, Boolean operators (‘AND’ & ‘OR’) and keywords referring to the provinces of the Amazonas region (‘Amazonas, Peru’, ‘Chachapoyas’, ‘Luya’; ‘Rodriguez de Mendoza’, ‘Utcubamba’, ‘Bagua’, ‘Bongara’, and ‘Condorcanqui’) were used. This time period (1960–2021) was chosen as it is contiguous with the first publication focusing on Amazonas. Besides the query terms, the data was limited to include research and review articles written in English, German, Italian, Portuguese, and Spanish. It is worth mentioning that Amazonas region refers to one of the 24 second level administrative areas of Peru. During our search, the term ‘Amazonas region’ was discriminated from others such as ‘Amazon region’ or ‘Amazonia’ or ‘Alto Amazonas’ referring to either Amazon river Basin or the Brazilian state.

The database (Table S1, doi.org/10.6084/m9.figshare.17161358.v2) grouped publications into the five regional components (C) and subcomponents (SC) of the CRDP (Figure 1) (GOREA 2014). To investigate in which component each article should be placed, we analyzed the words that are grammatically connected to each of the five regional components of the CRDP in the titles, abstract and key words of all the sampled articles. To this end, only terms that are directly relevant to the statements and overall vision of each component were analyzed (Klein and Manning 2003; Li, Rollins, and Yan 2018). Additionally, although this study focuses on the evaluation of research according to the current CRDP document, new subcomponents were added to include publications that are not included in this CRDP. Adding the new subcomponents avoids forcing the placement of the sampled articles in areas where they are not related.

Descriptive analyses of items associated with the five regional components of the CRDP (e.g. country, year, gender, ethnicity, province) were performed using tidyverse packages in R v4.1 software (Wickham 2017). Although the compound annual growth rate (CAGR) is an indicator commonly used to describe economic growth, the CAGR has also been reported to measure scientific growth (Hassan, Sarwar, and Muazzam 2015; Castillo and Powell 2019). The CAGR for the Amazonas region was calculated for periods of 20 years (1960–1980, 1981–2000, and 2001–2021) following the procedures of Castillo and Powell (2019). Cross-tabulation matrices and histograms were performed to analyze the relationship between CRDP components and research production. Additionally, a heatmap combining the five regional components of the CRDP with their own subcomponents was constructed to visualize a number of scientific articles. The subcomponents with the highest scientific production were correlated with their own environmental and socio-economic indicators to analyze the impact of research on these subcomponents (Tables S2–S3).

Network maps were constructed using the ‘full count’ method of VOSviewer v.1.6.17 software (Van Eck and Waltman 2010) to explore coauthorship (by countries, Peruvian regions, and institutions) and co-occurrence (words in article titles).

Results

A total of 386 scientific articles focused on the Amazonas region were published from 1960 to 2021 in high-impact journals indexed in SciELO (75) and Scopus/Web of Science (311) (Figure S1). The lowest number of published articles was reported from 1960 to 2006 (ranged 0–6 publications). Conversely, there has been a considerable increase in scientific production in recent years (~183 articles in the last four years) (Figure 2), and these articles have been published mainly in international journals (77%). This result is consistent with the values of CAGRs for the periods 1960–1980, 1981–2000, and 2001–2021, which were 5.6%, 0.0% and 16.4%, respectively. Analyses of corresponding authors regarding gender indicated that scientific publications focused on the Amazonas region were dominated by male researchers (75%) (Figure S2). However, this trend is slowly reversing, as there has been a visible increase in women as corresponding authors in the last two years (Figure 2). Unfortunately, there were no corresponding authors having an indigenous background, especially considering that indigenous communities Awajun, Wampi, and Quechua represent 16.5% of the population in Amazonas region (INEI 2020).

Regarding the five regional components of the CRDP, the highest scientific contribution was reported for C1 (environment and disaster risk) (224 articles) (Figure 3(a)). Additionally, significant contributions were reported for C2 (economy, competitiveness and employment) (65 articles), C3 (fundamental rights and dignity of people) (50 articles), and C4 (access to social services) (67 articles) (Figure 3(b–d)). Conversely, the lowest contribution was recorded for C5 (institutionalism and governance) (10 articles) (Figure 3(e)).
Nine additional subcomponents were added to the components of the CRDP to include some of the sampled articles. Two subcomponents were added to C1, five to C2 and two to C3. Heatmap analyses confronting the five regional components of the CRDP to its own subcomponents identified that the subcomponent biodiversity conservation (SC2) within C1 encompasses the highest number of scientific articles (178), whereas the subcomponent research, technology and innovation (SC4) within C2 did not record any articles (Figure 4).

To assess the impact of scientific findings on public policies in the Amazonas region, correlation analyses were performed among the number of published articles and each indicator contained in every component. The highest correlations found were those among the number of articles and four indicators (i.e. per capita family income, \( r = 0.791 \); accumulated surface of natural protected areas (NPA), \( r = 0.728 \); population affiliated with the Integral Health System, \( r = 0.699 \); flow of national and foreign tourists, \( r = 0.511 \)) (Tables S2–S3). However, only the indicator ‘Accumulated surface of NPA’ (within SC2 and C1) was impacted and favored by the increase in publications focused on the conservation of biodiversity (Figure 5). It is worth mentioning that although the other three indicators are correlated to the increase of publications, these are spurious correlations as they are associated but not causally related, due to the presence of a certain third factor (e.g. GDP).

Figure 1. Regional strategic components (C) and subcomponents (SC) of the CRDP of the Amazonas region. New subcomponents have been added in italics to group publications that were not included in the current CRDP.

Figure 2. Temporal dynamics of publications from 1960 to 2021 within the Amazonas Region highlighting the gender of the corresponding author. Note the increase in scientific production during the last two decades (CAGR\(_{1960-1980}\) = 5.6%, CAGR\(_{1981-2000}\) = 0%, CAGR\(_{2001-2021}\) = 16.4%).
Regarding the studied provinces of the Amazonas region, the highest number of articles was focused on Chachapoyas (226 articles), whereas approximately half of the publications were focused on the remaining provinces (Bagua, 144; Bongará, 130; Condorcanqui, 127; Luya, 117; Rodríguez de Mendoza, 116; Utcubamba, 116) (Figure 6(a–g)). Most of these articles encompassed research on components C1 and C4 of the CRDP (Figure 6(h)).

Over the last ∼60 years, 116 Peruvian institutions have performed research focusing on the Amazonas region (Figure 7(a)). Of these, only two national universities Universidad Nacional Toribio Rodríguez de Mendoza, UNTRM and Universidad Nacional Mayor de San Marcos, UNMSM have contributed significantly, with 86 and 61 publications, respectively. The National Institute of Health (INS) and Universidad Nacional de Trujillo (UNT), with 17 and 11 publications, respectively, are other institutions with a significant scientific contribution. A temporal analysis showed that INS, UNT and UNMSM have been pioneers regarding scientific contribution, while UNTRM has produced a striking number of articles in recent years (Figure 7(a)). Additionally, 222 foreign institutions have collaborated with Peruvian entities to perform research in the Amazonas region, such as the Neotropical Primate Conservation (10 articles), University of California (9), Università degli Studi di Napoli Federico II (7), and University of Texas (6). In Peru, research institutions located in Lima and Amazonas have contributed significantly to the study of the Amazonas region (Figure 7(b)), as they have produced 144 and 111 articles, respectively. Other regions neighboring Amazonas, such as La Libertad, Cajamarca and Lambayeque, made minor contributions by publishing 18, 13, and 10 articles, respectively.

A total of 1286 words were identified in the titles, of which 148 appeared more than three times (Figure 8). The words with the highest occurrence in publications belonging to component C1 were ‘species’ (65 articles), ‘genus’ (14), and ‘forest’ (10) (Figure 3S). Articles grouped in component C2 had the highest occurrences (five articles) for the words ‘bovine’, ‘native’, ‘cocoa’; ‘species’, ‘silvopastoral’, ‘invitro’, ‘coffee’, and ‘zinc’ (Figure 4S). In C3, ‘history’, ‘awajun’, ‘community’, and ‘archaeological’ occurred in six, five, four and three articles, respectively (Figure 5S). In C4, the keywords ‘community’ (9), ‘awajun’ (7), ‘health’ (7), ‘factors’ (6), ‘COVID-19’ (5), and ‘Leishmania’ (5) were the top-listed (Figure 6S), while in C5, the words ‘politics’, ‘management’, ‘children’, and ‘awajun’ occurred in two articles (Figure 7S).
Discussion

Scientific production has largely increased in the last 20 years in the Amazonas region (CAGR\textsubscript{2001-2021} = 16.4%), especially in the last four years, where 183 articles have been published (Figure 2). This publication rate is higher than the national average (11.2%) and that of other countries in the region, such as Ecuador (15.7%), Colombia (14.8%), Brazil (6.6%), Argentina (5.2%), and Mexico (4.6%), during the same period of time (Barreto, Rodríguez, and Chávez 2021).

Figure 5. Correlation of the indicator accumulated surface of NPA with the number of articles focused on conservation of biodiversity (SC2) in C1 of the CRDP.

Figure 6. Number of articles focused on the provinces of the Amazonas region from 1960 to 2021 (a-g) and proportion of articles according to each component of the CRDP (h).
Historically, UNMSM has been the institution with the largest scientific production in the Amazonas region; however, in the last 15 years, UNTRM (a national university located in Chachapoyas) has taken leadership in terms of scientific contribution (Figure 7). This striking progress in the publication of scientific articles is a consequence of a major investment in GDP in R&D policies (Limaymanta et al. 2020), which is reflected mainly in (i) the increase of project funding and funders and (ii) the incorporation of specialized researchers (Moquillaza 2019). For instance, CONCYTEC (Peruvian National Council for Science, Technology and Technological Innovation), PNIA (National Agricultural Innovation Program), and FINCYT (Fund for Innovation, Science and Technology) granted a total of over 2 million USD for 10 projects to UNTRM in 2017 (UNTRM 2021a). Currently, this university is conducting 34 new projects from the above-mentioned sources (UNTRM 2021b). Additionally, the Law for the Promotion of the Development of Scientific Researchers promotes the work of highly specialized scientific researchers through the recognition of their professional careers and achievements. This policy also encourages the establishment of mechanisms to attract and retain national and foreign investigators (CONCYTEC 2019; 2021). These two mechanisms were allowed after SUNEDU (National Superintendence of Higher University Education) granted licensing to universities from the Amazonas region (SUNEDU 2017).

The large gender gaps regarding corresponding authorship (25% female researchers) have not been overcome in the high rate of publications in the Amazonas region. Currently, in Peru, only 31.9% of women enter in science-related careers, with sociocultural conflicts and stereotypes being the main factors limiting their participation (CONCYTEC 2016b). However, this scenario might change drastically as more female participation is encouraged in research projects by granting additional points for STEM proposals. Currently, one woman awarded a national science prize is currently conducting STEM research in the Amazonas region (CONCYTEC 2021). Additionally, this work revealed the absence of indigenous representation in research and encourages the incorporation of local actors outside of academia to create ownership in research agendas and break up the unilateral knowledge transfer.

This study indicates that a larger number of publications are related to the environment and disaster risk component (C1) of the CRDP, specifically associated with the subcomponent of biodiversity conservation and ecosystem services (SC2) (Figures 3 and 4). Additionally, ‘species’ was the main word for this component, with topics regarding organisms of economic and ecological importance. This scenario highlights the environmental and ecological value of the Amazonas region, which registers 11 out of 39 different ecosystems of the country (MINAM 2019; BCRP 2021) and includes 27 natural protected areas (SERNANP 2020). This region...
encompasses areas from low- and high-rainforests to highlands (Andes) and currently hosts abundant biodiversity (i.e. 36.6% mammals, 19.7% amphibians and reptiles, and 53.2% birds registered in Peru) (MINAM 2009), making it an attractive research hotspot (Jones and Solomon 2013; Cook, Edwards, and Lacey 2014; Boiral and Heras-Saizarbitoria 2015; Funk 2018).

Moreover, the recent increase in scientific production for the components regarding economy, employment, social services, population rights and cultural diversity (i.e. C2, C3, C4; Figure 4) reveals researchers’ commitment to understanding their impact on the development of the Amazonas region (Reátegui et al. 2018; Altea 2020; Mick et al. 2021). For instance, the main words for articles grouped in component C2 were ‘bovine’, ‘cocoa’, and ‘coffee’ corresponding to studies on biotechnology, zoometrics, silvopastoral systems, and agriculture (Cortez et al. 2017; Oliva et al. 2017; Pizarro et al. 2020). These publications are looking to maximize the growth of livestock and farming sectors in the region. ‘History’ was the main word in publication in component C3, with articles focusing on cultural richness (Leiva-González et al. 2019). This highlights the importance of the Chachapoyas and Awajun cultural heritage, ideas that are reinforced by the presence of over 900 tourist centers along the Amazonas region (MINCETUR 2017). In component 4, ‘community’, ‘awajun’, and ‘health’ were the main words based on issues regarding the formalization of rights, legal strategies in the defense of Amazonian territories, and the impact of COVID-19 on the economy and health of people from Amazonas (García, Veneros, and Tineo 2020; Aguilar León et al. 2021). On the other hand, the limited article contribution for the component of institutionalism and governance (C5) should empower researchers from the social and political science to embrace topics regarding public management, transparent administration, and efficient use of resources (GOREA 2014).

Despite the increase in scientific production in recent years in the Amazonas region, there is no strong linkage between the number of articles published and component indicators of the CRDP [i.e. per capita family income (2001–2017) (Liceras 2020), flow of domestic and foreign tourists (2010–2019) (Sánchez 2020), and the population affiliated with the Integral Health
that increase in article publication is not responsible of the improvement in other indicators of the CRDP, except in the accumulated surface of NPA.

The almost double number of articles focused on Chachapoyas Province compared to the other provinces of the Amazonas region suggests that this city has strongly contributed to scientific production (Figure 6). A city’s publishing efficiency is high if, for instance, the city is home to universities and research institutions and researchers affiliated with these institutions collaborate with researchers affiliated with cities of developed countries (György 2018). Accordingly, Chachapoyas is home to UNTRM, which is composed of 13 research institutions where ~50 researchers are collaborating with researchers from the USA, South Korea, and Germany (CONCYTEC 2021). These collaborations focus mainly on biodiversity, biotechnology, genetics, and industrial technology. This finding suggest that Chachapoyas is further ahead in scientific development compared to the other provinces. This potentiality should be channeled to achieve the aims of the five components of the CRDP.

Although Amazonas is the third poorest region in Peru, it has shown accelerated progress in scientific production as a consequence of the establishment and licensing of two national universities (UNTRM, UNIFSLB) (SUNEDU 2017; 2018). This has greatly improved the quality of education (i.e. higher rates of access to education at university, reduction in illiteracy rate; INEI 2020) and has generated knowledge for maximizing economic activities such as productive chains of cocoa, coffee, rice, and the tourism and bovine sector (DIRCETUR 2010; GOREA 2014; MINCETUR 2017). However, the continuous increase in scientific production requires policies with financial programs that ensure the sustainability of research projects over time (García, Veneros, and Tineo 2020). Additionally, increasing funding, recognition of researchers (especially women and natives), and empowerment of vigilant institutions (e.g. CONCYTEC, SUNEDU) have shown to be key factors for scientific development, which might impact quality of life standards and regional indicators. Moreover, scientific research should be promoted in collaborative networks among universities, research centers, and the private sector with a holistic and multidisciplinary vision to reduce the current separation of sociocultural, geostrategic, and financial factors (Boiral and Heras-Saizarbitoria 2015; Salvia et al. 2019; Millones-Gómez et al. 2021).

Academia tends to focus on generating scientific knowledge highlighting scientist’s technical competences (through training and collaboration) without including transdisciplinary research that facilitate the
identification of societally relevant problems, mutual learning processes from different disciplines, and transferable solution-oriented knowledge (Lang et al. 2012). Accordingly, scientific research performed by academia focusing on Amazonas region is failing to fully board the overall sustainable components of the CRDP. Social sciences are clearly understudied (e.g. rights of indigenous & vulnerable communities; basic services; modern, decentralized, transparent and efficient management), while research focused on innovation and technology has no published articles. However, this last finding can be underestimated due to innovation and technology is an emerging discipline in Amazonas region where researchers prioritize patents over the publication of scholarly articles.

The prevalence of research focused mainly on natural science (C1) reflects how Amazonas region is perceived by national and international scientists, as an unexplored area with a large biodiversity potential that is awaiting the discovery of natural resources. It is the role of regional institutions (government, universities, industry, non-profit, etc.) to ensure the extension of the research topics that cover other dimensions of scientific knowledge and social needs. Additionally, national and regional governments are missing the investments to develop and sustain the socioeconomic and political structures that facilitate knowledge creation (Mormina 2019) reducing unequal opportunities for research between scientific and social actors (Parker and Kingori 2016). Thereby, it is important that local policymakers take into consideration emerging disciplines (i.e. new sub-components of this study such as soil management, social psychology, industrial legislation, environmental legislation) that can provide an updated perspective in developmental policies in the Amazonas region.

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