Bright Spots and Blind Spots

A kick-ass project

11 March 2020

Contents

Abstract

Intro

The famous Blue Marble photograph taken by the crew of Apollo 17 embodies the abundance of water that supported the emergence of life on Earth and is intrinsically linked to human health, ecosystem function, and economic prosperity. Yet, this iconic picture belies the pressures facing freshwater resources today, brought about by anthropogenic threats of human population growth and urbanization (Jenerette and Larsen 2006; Immerzeel et al. 2020), climate variability and change (Gosling and Arnell 2016), economic growth and consumption patterns (Mcdonald et al. 2014; O'dorico et al. 2018), and the spread of misinformation and mistrust in science (IPCC 2014). To support societal and ecological water needs in this context, decision-making must be based on evidence from robust water resources research in a diversity of scientific fields (Uzzi et al. 2013). A typical combinations and scientific impact, which spans spatial (Zipper et al. 2020) and temporal scales of resource management, and is connected by collaborations within and across countries and disciplines (Astudillo 2016). This definition of robust research can be used to identify bright and blind spots of past scientific inquiry, that is topics and locations where water issues are more- or less-thoroughly understood, respectively (Cvitanovic and Hobday 2018).

Latin America embodies these water challenges with its unequal distribution of abundant water resources for a small population (DESA 2019), mounting pollution and the highest income inequality in the world (Varis, Taka, and Kummu 2019). Marked disparities between and within countries affect water resources management, such as water supply, climate change vulnerability, urbanization level, habits and scientific productivity (Ciocca and Delgado 2017; Lyon et al. 2019). Countries with abundant surface water resources, such as Brazil, experience water scarcity due to a mismatch between water-ich areas and population centers (Formiga-Johnsson and Kemper, n.d.), while others face flooding and melting glaciers, such as Argentina, Chile and Bolivia (Barros et al. 2015; Soruco et al. 2015; Masiokas et al. 2019). Latin America is among the most urbanized regions in the world and these high density areas face particular vulnerability to water

quality and supply risks (Kim and Grafakos 2019). The city of Sāo Paulo nearly ran out of water during a 2014 drought, while Mexico City is steadily and rapidly depleting its groundwater supply (Aguilar-Barajas et al. 2015). Urban pressures on water resources are compounded by poor farming practices, unregulated industries, and aging infrastructure across the region. These water challenges are expected to intensify due to climate change as variations in precipitation, temperature, and evaporation threaten water availability for current and future water users around the globe, and particularly in Latin America (Dussaillant et al. 2019; Garreaud et al. 2017; Gesualdo et al. 2019; Zaninelli et al. 2019). Uncertainty surrounds the reliability of water supplies to meet future needs as well as the availability of funds for scientific research to address future water scarcity (Andrade 2019). There is a need for comparative research within Latin America, rather than comparisons within and between the United States and Europe where scientific and monetary resources have been comparatively more plentiful.

Challenge

Given these circumstances, it is critical to assess whether water resources research across Latin America contributes the knowledge necessary to successfully manage water. Water resources management is a relatively young scientific discipline (Montanari et al. 2015) and review papers up to this point often focus on a small geographic area (Chowdhury 2010; Owusu, Asumadu-Sarkodie, and Ameyo 2016; Digna et al. 2017; Araujo et al. 2015), individual component of the water budget (Dobriyal et al. 2012; Berndtsson 2010), particular methodology (Dong et al. 2013; Plummer, Loë, and Armitage 2012) or specific water user (Singh, Kazmi, and Starkl 2015; Ran et al. 2016; Arbués, Garcıa-Valiñas, and Martınez-Espiñeira 2003).

To assess the state of this research, we performed an unprecedented, multi-lingual review of the state of water resources research literature in the region and across a range of topics and disciplines. This literature review reveals bright spots and blind spots of past water research and provides insights for scientists and decision-makers to advance the relevance and impact of future scientific inquiries and to design effective policy solutions to resource management challenges.

Methods

Our two-fold, novel and comprehensive research approach combines advanced computation with a stakeholder survey to describe past water research in Latin America. First, we performed a data-driven literature review by assembling a corpus of 30,000 water resources research articles and analyzing them with a topic model. We used Latent Dirichlet Allocation (LDA, (Blei, Ng, and Jordan 2003)), a generative Bayesian model, which describes topics as a probability distribution over words and documents as a probability distribution over topics. Human reading validated the document topics and identified the country of study of 2,000 articles. Combined with article metadata and text mining, this information was used to predict the country of study across the corpus with machine learning. In-corpus citing and cited references were used to build a citation network which, combined with topic and location information, infers connectivity between research communities.

Second, to understand the landscape of water research in Latin America, we collected publicly available data and conducted an on line survey. Countries within Latin America were statistically clustered into four groups with distinct physiographic and socioeconomic characteristics. To ground our data-driven results in the reality of the current research climate, we invited nearly 20,000 corresponding authors to share their experiences through a survey focused on research discipline, accessibility and connectivity.

Results & Discussion

Time line

The scientific production of water research based in Latin America and the Caribbean has grown exponentially over the last four decades, revealing a significant contribution of knowledge that this region is providing to the global scientific community. We grouped research by country cluster, which we calculated using 43(?)

variables, to identify how countries with similar social and hydrological systems contributed to water research over time. The growth in research is not distributed equally across the region and is dominated by contributions from the two largest countries in Latin America, Brazil and Mexico. A residual analysis of the exponential growth of annual research by country cluster identifies trends in annual scientific output. Since 2000, the first year when we have over 30 research papers in each language, there were three distinct periods of water research. Annual output was lower than the general trend for the first several years of the 21st century, followed by a period of relatively higher output and ends with a trend of decreasing growth. There may be a connection between Brazil's economic crisis in 2012….

Chord diagram

A chord diagram describes the composition of water research in Latin America and the Caribbean and reveals inequalities in locations and themes of research (figure 1). The chord widths indicate the proportion of a specific research theme within the top 25% of research for a given country. While Brazil, Mexico, Argentina and Chile dominate the research landscape, countries in the Caribbean and most of Central America are excluded from the analysis due to their statistically insufficient number of articles (less than 30), indicating a relative shortage of research in these regions. A country's socio-economic cluster correlates to its contribution to overall research output, suggesting that a country's resources, geography and history influence the scientific activity of researchers working there. Similarly, water research is not distributed equally among disciplines and there is a relative shortage of research in the social sciences. While Mexico contributes most to the social science research, it is a small proportion of its overall output. Water research is conducted primarily in the physical and life sciences, with Mexico and Argentina alternating for second highest output after Brazil, respectively.

After assessing trends in the corpus, we further analyzed results from the topic model and text mining to identify bright spots and blind spots of water research in Latin America and the Caribbean. We define successful research as having a distribution that is close to the standard normal distribution and with high entropy. When applied to our corpus, these concepts highlight areas within water resources research that are relatively under-studied.

Normality

Water research in Latin America and the Caribbean has generally higher normality across countries than documents (figure 2). A review of the normalities of the components of the water budget validates our analysis approach. Rivers and precipitation, which must be monitored and understood to manage water resources, have distributions closest to normal, while glaciers are far from normal distribution because few countries have glaciers to study. Assuming that high normality indicates success, we identify statistics, quantitative methods and water sampling as bright spot of research methods. Niche topics, such as irrigation and isotopes, have high normality across countries but low normality across documents and lie somewhere between bright and blind spots. Such research topics are either infrequently mentioned or, if mentioned, are the main subject of a paper and lack integration in interdisciplinary research. The least normality is seen in two topics of great importance for water management: reservoirs and risk assessment.

Maps

Network analysis

LDA performance

All of this research

1/3 of the NSF specific categories present in our corpus are present in all 3 languages

Importantly, most of the top 10% of research is captured in thee categories in all 3 languages (9 of 13)

Another 1/3 is in 2 languages and the last 1/3 is only present in English

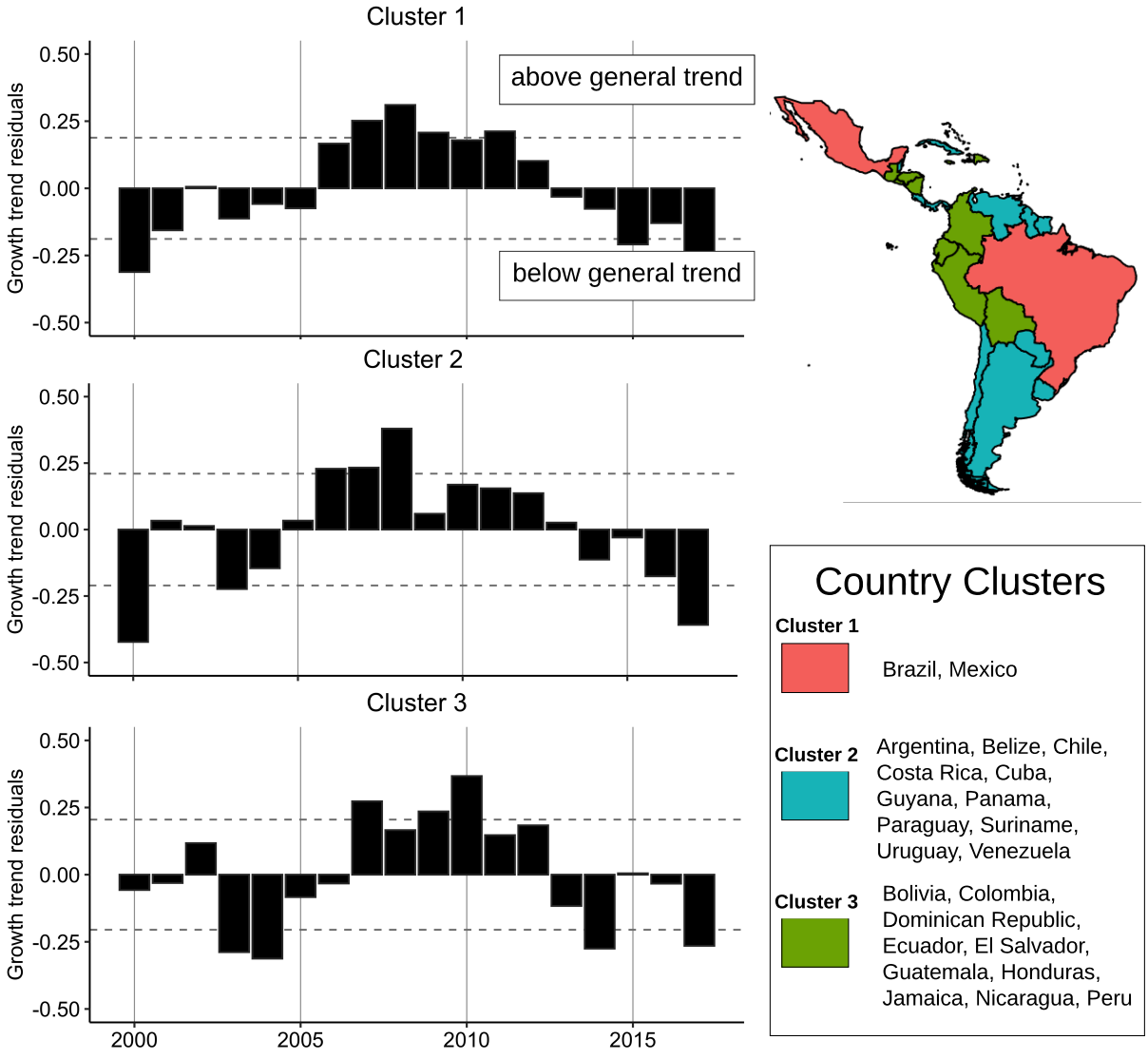

Figure 1: Time line

Results from the topic model can accurately describe the research occuring in all 3 languages in most categories

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