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Water-Energy-Food nexus status in Brazil

Status do Nexo Água-Energia-Alimentos no Brasil

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ABSTRACT

This article investigates the relationship between the water-energy-food (WEF) nexus in Brazil in an exploratory and statistical study over the period from 2000 to 2013. For that purpose, the explanatory variables considered were the following: Access to improved water; Access to electricity and Average protein supply. Furthermore, some brief facts about WEF nexus security in Brazil was introduced. With such explanatory variables, descriptive statistics was performed, ensuring the assumption of data normality approach, and consequently calculating the descriptive statistics and correlation. The results of correlation showed that the quantitative relation between the three factors was extremely strong. These data allowed to understand the relation between these indicators and its status as a nexus in Brazil. Therefore, it is concluded that pursuing an active policy to manage demand in WEF nexus could lead sustainability processes.

Keywords: Security. Scarcity. Natural resources. Policies. Sustainability.

RESUMO

Esse artigo investiga a relação entre o nexo água-energia-alimentos (AEA) no Brasil em um estudo exploratório e estatístico durante o período de 2000 até 2013. Para esse fim, as variáveis explanatórias consideradas foram as seguintes: Acesso a água potável. Acesso a eletricidade e Oferta média de proteína. Além disso, introduziu-se alguns fatos breves sobre a segurança do nexo AEA no Brasil. Como essas variáveis explanatórias, realizou-se a estatística descritiva, assegurando a assunção da abordagem de normalidade dos dados, e consequentemente calculando a estatísticas descritiva e sua correlação. Os resultados de correlação indicaram que a relação quantitativa entre os três fatores foi extremamente forte. Esses dados permitem entender a relação entre os indicadores e o seu status como um nexo no Brasil. Portanto, é concluído que possuindo uma política ativa para gerir a demanda do nexo AEA pode conduzir a processos sustentáveis.

Palavras-chave: Segurança. Escassez. Recursos Naturais. Políticas. Sustentabilidade.

INTRODUCTION

Sustainability is an increasing concern in the society, because of the depletion of natural resources and concerns about the disparity of wealth and corporate social responsibility (Govindan et al., 2013). Therefore, public and private policy tools are required to adequately qualify the relationship between the sustainable Water-Energy-Food (WEF) nexus approach in order to identify and evaluate the trade-offs and synergies that would be needed to be considered as human economies continue to grow.

Adequate access to WEF resources lacks on a substantial percentage of the global population. Although efforts have increased their access within the past 15 years, 800 million people are still considered food insecure, 800 million lack access to safe drinking water, and 1.2 billion lack access to electricity (Scalon et al., 2017).

WEF are some of the most important resources for societies around the world. Demands for these resources are increasing rapidly due to increasing population, increasing income, and changing lifestyles. In this context, WEF securities have been discussed separately, however, these three issues should be considered in an integrated manner, because they are inherently connected and their utilization may result in important tradeoffs (Taniguchi et al., 2017).

The literature on the WEF nexus (or "nexus" for short) expresses great ambitions to achieve policy coherence and overcome the unintended consequences of uncoordinated policy between different sectors. The nexus concept is intuitively compelling, spawning conceptual frameworks, and analytical tools (Weitz et al., 2017).

For this purpose, it is essential interdisciplinary research for effective management of WEF systems. While the various science disciplines have long histories of working independently in components of the WEF nexus, future research should integrate physical, agroecological, and social sciences with economics (Scalon et al., 2017).

Nevertheless, preferences for different measures for handling nexus issues will vary according to different perspectives on the nexus and, if adopted, steer in different directions mainly for each country (Weitz et al., 2017).

However, analytical insight by itself does not produce effective and accountable policy and management and based on the fact that Brazil as a developing country might have a specific policy on that issue. This article can be an attempt to evaluate the WEF nexus status in Brazil, which can be a relevant contribution to this research field enabling new different actions implemented in different contexts.

Therefore, the current research aims to analyze the Water-Energy-Food nexus status in Brazil in order to evaluate how is the connection between them and enable public or private information to help decision makers.

METHODOLOGY

Overview

The objective is to evaluate de relation between the Water-Energy-Food nexus in Brazil. It began by researching a deep literature review on the theme enabling the evaluation of the best indicators to be chosen for the Brazilian case.

Data source and collection

Data from the following indicators for each of the WEF systems was collected, for a period from 2000 until 2013:

For water security, the indicator used was: Access to improved water sources (%) (3-year-average). It refers to the percentage of the population with reasonable access to an adequate amount of water from an improved source, such as a household connection, public standpipe, borehole, protected well or spring, and rainwater collection. Unimproved sources include vendors, tanker trucks, and unprotected wells and springs. Reasonable access is defined as the availability of at least 20 liters a person a day from a source within one kilometer of the dwelling (FAOSTAT, 2017).

For energy security, the indicator used was: Access to Electricity (% of the population). It refers to the percentage of people in a given area that have relatively simple, stable access to electricity. It can also be referred to the electrification rate. Not all countries and areas have equal access to electricity, and the level of access can be indicative of the development level of the country or area in question (World Bank, 2017).

For food security, the indicator used was: Average Protein supply (g/capita/day). It measures the national average protein supply (expressed in grams per caput per day) and provides information on the quality of the diet (FAOSTAT, 2017). The data collected is showed in Table 1.

Table 1 – Data used to analyze the WEF nexus status in Brazil.

Years (3-year average)	Average Protein supply (g/capita/day)	Access to improved water sources (%)	Access to electricity (% of population)
2000-2002	99	93.83	95.71
2001-2003	101	94.17	96.55
2002-2004	103	94.53	96.80
2003-2005	103	94.87	96.95
2004-2006	104	95.23	97.15
2005-2007	105	95.57	97.60
2006-2008	108	95.90	98.08
2007-2009	109	96.20	98.50
2008-2010	111	96.53	98.85
2009-2011	112	96.87	99.12
2010-2012	114	97.20	99.34
2011-2013	116	97.50	99.47

Statistical test

The analysis was performed according to two discrete steps. First, the observations were sorted into relevant graphs for each regulatory factor. Consequently, for each indicator respectively, basic descriptive statistics (means and standard deviations) were calculated to provide both quantitative and visual information.

Second, the data were assessed in terms of satisfying certain assumptions and these results were used to formulate the correlations. Correlation Statistical test requires the assessment of one basic assumption about the statistical population: (1) the normality of the distributions.

Assessing the assumption of normality is of paramount importance for deciding the use of a parametric or non-parametric statistical test. The parametric statistical analysis assumes a certain distribution of the data, namely the "normal" one, which in case of violation may lead to invalid and unreliable interpretation and inference (Razali and Wah, 2011). On the contrary, non-parametric statistics are distribution-free methods and therefore do not rely on the estimation of population parameters (StatSoft, 2015).

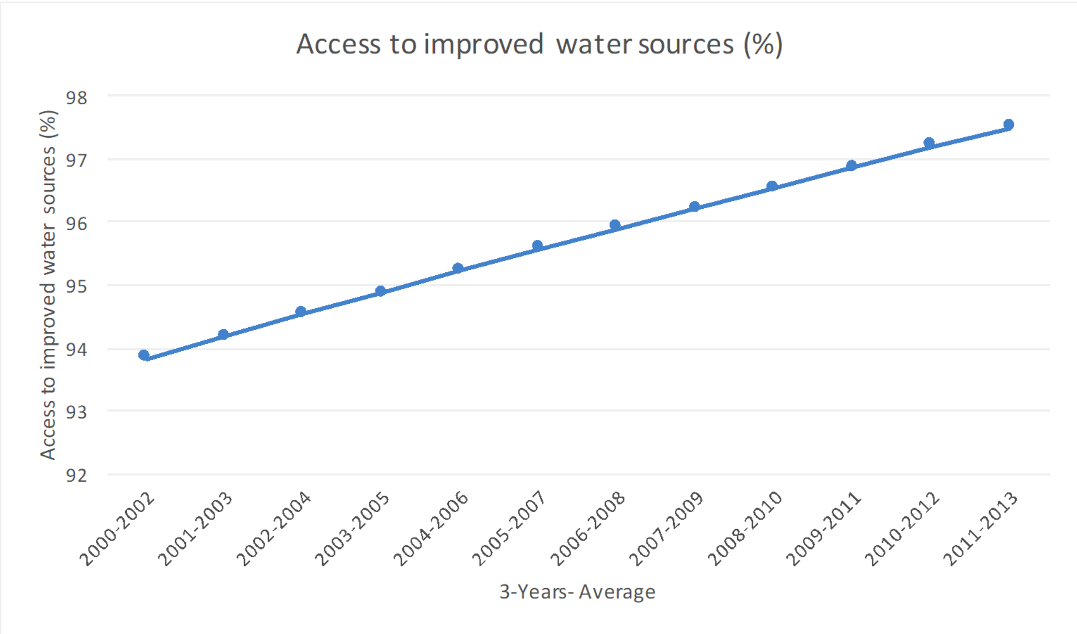
To check the normality of the distribution, the Shapiro-Wilk test (SeW test) was performed against the alternative of Kolmogorov-Smirnov test. The SeW test is considered the most powerful normality test available (Razali and Wah, 2011).

Finally, the statistical correlation was tested according to a selected level of significance with Pearson Correlation. Statistical analyses were performed with SPSS Statistics V20.0 (Preacher and Hayes, 2004).

RESULTS AND DISCUSSION

The Access to improved water in Brazil is shown in Figure 1:

Figure 01 – Access to improved water sources x 3-years-Average from 2000 to 2013 (%)



Source: FAOSTAT (2017).

Figure 1 showed that the access to improved water sources is almost reaching 98%. Brazil is a country of continental dimensions, which holds some of the largest river basins on the planet (Vilanova and Balestrini, 2015) and has a large legislation about its use.

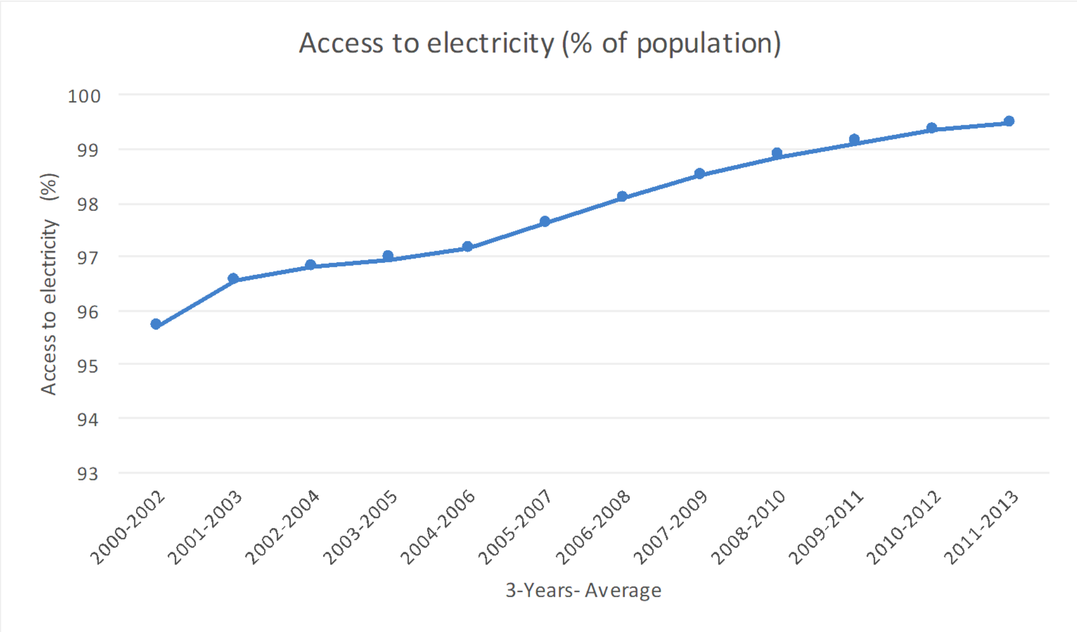
Existing Brazilian environmental legislation concerning water used for consumption and bathing includes Regulation 2914, from the Ministry of Health, and CONAMA Resolution n. 274, respectively. Regulation 2914 (formerly Regulation 518) from the Ministry of Health describes the water quality and portability using microbiological, physical, chemical, and radiological parameters. CONAMA Resolution n. 274 includes parameters indicating the suitability of surface waters for activities such as bathing and water sports (CONAMA, 2017).

However, Brazil still has challenges to deal with respect to the water security. Though 73% of all fresh water available in Brazil is located in the Amazon basin, the total of inhabitants in this area represents less than 5% of the entire Brazilian population. Indeed, the Brazilian semiarid suffers from severe water scarcity which originates basically from a combination of recurrent droughts and environmental degradation (Silva et al., 2016).

Moreover, Brazil is the world leader in the production and export of agro-livestock goods. The environmental impacts caused by the water resources transfer embedded in all agricultural and livestock products that flow from Brazil to other countries are still unknown (Orlowsky et al., 2014). However, water supply is becoming an increasing concern for farmers, hence farmers are opting for irrigation and efficient use of available water (Drastig et al., 2016).

The average Access to electricity (% of population) in Brazil is shown in Figure 2:

Figure 02 – Access to electricity x 3-Years-Average from 2000 to 2013 (%)



Source: Word Bank (2017)

As is showed in Figure 3 the Brazilian access to electricity reaches almost 100%. Electricity became a government priority in Brazil in the 1930's, during the military and later democratically elected administrations of President Getúlio Vargas (1930-1945; 1951-1954) and his national industrialization projects. In 1934, the Brazilian central government took charge of all of the phases of the electricity industry (Tolsmasquim, 2011).

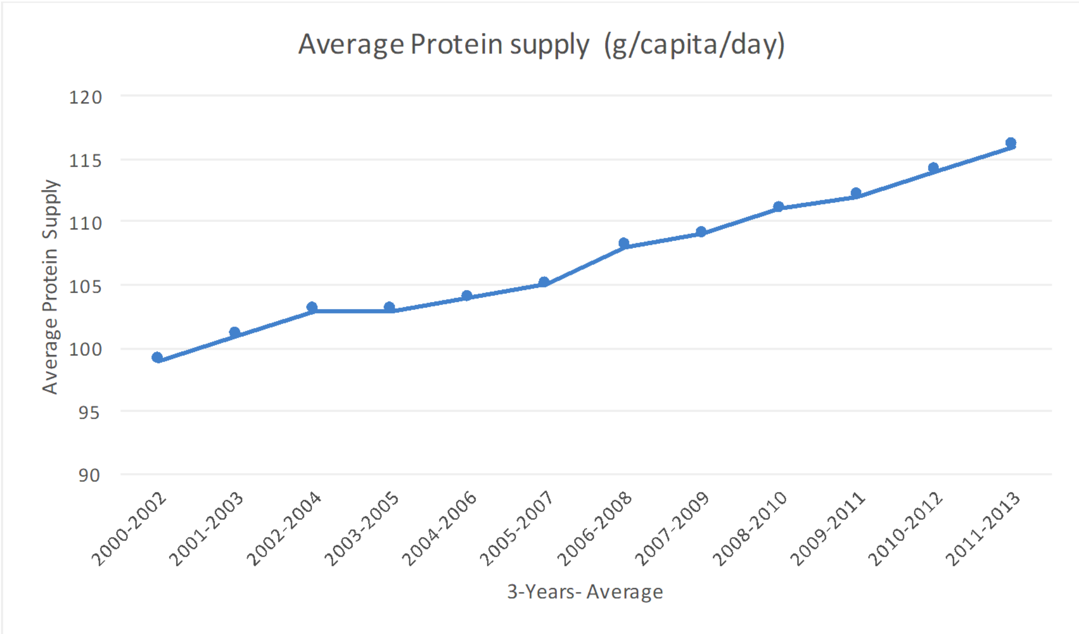
Access to Electricity in Brazil has improved significantly since 2003 when the Federal programme Light for All (*Luz para Todos*) was introduced during the first administration of the President Lula (2003-2011). To date, the program has provided electricity to over 15 million Brazilians through the extension of the centralized grid (MME, 2014). According to the latest household survey conducted by the Brazilian

Statistical Agency (IBGE), there are approximately 234,000 households without electricity access in Brazil but the overall electrification rate is 99.7% (PNAD, IBGE, 2015).

However, the hydroelectric power generation in Brazil has proven to be vulnerable to extraneous scenarios leading to unpredictability since 2015, the year in which a severe drought affected the populated states of Sao Paulo and Rio de Janeiro, reducing the efficiency of hydroelectric power plants. As an alternative, thermoelectric plant operations increased to fill the gap, further expanding the use of fossil fuels thereby increasing greenhouse gas (GHG) emissions and the price of electricity (The Guardian, 2015). According to the Brazilian Electricity Regulatory Agency (ANEEL), the industrial price of electricity in the Southeast region increased from 80.94 to 131.25 US$/MWh during 2012–2016 (Brazil, 2016).

The average Protein supply in Brazil is shown in Figure 3:

Fig 3: Average Protein Supply x 3-Years-Average from 2000 to 2013 (g/capita/day)



Source: FAOSTAT, 2017.

As can be seen in Figure 3, the average protein available in Brazil is increasing but it has not been like that all the time. Social inequality has been permeated by Brazilian people since its colonization and by black people's slavery, brought from Africa. Historical reflections of oppression periods are present in the society up to now including demanding the hunger factor (Senna and Souza, 2016).

In the last years, the Federal government started to worry about food security programs. Starting with a program called Bolsa Família, whose early components originated in the late 1990s and rapidly expanded in recent years. This program distributes funds to households with school children and income below a certain level with monthly cash transfers (Lemos et al., 2016).

After that beginning, the Brazil's multisectoral food and nutrition security strategy (*Segurança Alimentar e Nutricional*, or SAN) developed from 2003, prioritized the expansion of school meals and brought significant changes in the programme's design and implementation. The creation of the Food Acquisition Programme (called PPA), for example, developed as part of the SAN to guarantee regular and sufficient access to food to those in situations of food and nutritional insecurity, was also widely used by local authorities to supplement school meals (Kleine and Brightwell, 2015).

Included in 2003, Brazil has implemented an encompassing social reform under the general umbrella of the Zero Hunger (*Fome Zero*) Program. This anti-poverty intervention aims to improve inequality and human development indicators (HDI - increase income and access to education and decrease of infant mortality rates) as well as creating jobs and increasing food security (Brauw et al., 2014).

However, according to the Brazilian Institute of Geography and Statistics (called IBGE), it is identified 37.5% of households with some level of food insecurity, and among them, at least 45.5% are children under 5 years old. And it still has 3.2% of the population in urban areas and 5.5% of the population in rural areas with severe food insecurity (severely constrained access to food, measured using the Brazilian food insecurity scale) (IBGE, 2014).

Statistical Tests

At its core, this study is concerned with three distinct criteria showed in Table 1. For each analyzes it had 8 observations for 3-year-average analysis as can been seen in Table 2 with the descriptive statistics test.

Table 2 – Descriptive statistics from the 3 analyzed measures: Mean; Standard Deviation; Max/min and N. Obs.

Factor	Mean (X)	Standard Deviation	Max/Min	*N. Obs.
Average Protein supply (g/capita/day)	107.08	5.401	116/99	12
Access to improved water sources (%)	95.7	1.20462073	97.5/93.83	12
Access to electricity (% of population)	97.8423889	1.2310896	99.47/95.71	12

Note: The abbreviation "N. Obs." Stands for the term "number of observations"

As shown in Table 2 the average protein supply means is 107,08 g/capital/day analyzing from the year 2000 until 2013. According to the United States National Health Nutrition Examination survey, the recommended dietary allowance (RDA) for protein consumption is 0.8 g/Kg body weight/day (Deutz et al., 2014). Which means that if an adult individual has from 70 Kg to 100 Kg, he or she must consume at least from 56 g/day until 80 g/day. It shows that in Brazil at average it has more than that amount per day. Therefore, it is concluded that it is a good rate of protein supply.

Indeed, the access to improved water sources has a mean of 95,7%. According to the Food and Agriculture Organization of The United Nations, Brazil has a good rate of these criteria, comparing to some neighbor's countries. For instance, in 2013, Ecuador had 86.4% rate, Paraguay had 95.0%, Venezuela had 93.1% less than Brazil but Argentina had 98.8% and Uruguay had 99.5% a little bit more than Brazil (FAOSTAT, 2017).

The access to electricity had a mean of 97.84%. However, the total electricity consumption in Brazil is still small compared with developed countries; the total electricity consumption was 2.94 MWh/person in 2011 while in developed countries it was between 5 MWh/person and 24 MWh/person. The residential and industrial electricity consumption is expected to increase in Brazil in the coming years to accommodate a possible economic (Villareal and Moreira, 2016).

The assumption of normality

Overall, the results of the normality test used, provided evidence in support of the assumption of the normality beyond the data. These results are shown in Table 3.

Table 3 – Normality test from the 3 analyzed measures: Shapiro Wilk and Kolmogorov –Smirnov test.

Factor	Shapiro-Wilk	Kolmogorov - Smirnov
Average Protein supply (g/capita/day)	0.803	0.2
Access to improved water sources (%)	0.87	0.2
Access to electricity (% of population)	0.59	0.2

According to the results, all variables satisfy the Kolmogorow–Smirnov test as well the Shapiro–Wilk Test of normality ($p>.05$). Therefore, it is allowed to perform the parametric test correlation of Pearson without transforming any variable (Ramesh et al., 2016).

Correlation test

The results of the normality test used, provided also evidence in support of the assumption of correlation beyond the data. The correlation result is showed in Table 4.

Table 4 – Parametric Pearson Correlation test from the 3 analyzed measures and its Significance.

Factor	-	Average Protein supply (g/capita/day)	Access to improved water sources (%)	Access to electricity (% of population)
Average Protein supply (g/capita/day)	Pearson Correlation	1	0.990**	0.988**
	Sig. (2-tailed)	-	0	0
Access to improved water sources (%)	Pearson Correlation	0.990**	1	0.991**
	Sig. (2-tailed)	0	-	0
Access to electricity (% of population)	Pearson Correlation	0.988**	0.991**	1
	Sig. (2-tailed)	0	0	-

** - Correlation is significant at the 0,01 level (2-tailed).

According to the results, all variables have a Strongly Positive correlation according to Pearson Correlation. All the results represent more than 98% of correlation, which means that they are extremely connected in Brazil reflecting the context of a nexus.

According to the climate, energy and tenure division from Food and Agriculture Organization (FAO) of the United Nations the WEF nexus means that the three sectors - water security, energy security and food security - are inextricably linked and that actions in one area have impacts in one or both of the others (Flammini et al., 2014).

The first perspective on the nexus focuses on risk and security, which is based on the idea that failing to account for connections between nexus sectors could worsen resource scarcity and induce conflicts (Weitz et al., 2017). Moreover, to enhance their security, is needed to increase efficiency, reduce trade-offs, build synergies and improve governance across sectors (Hoff, 2011).

Studies have been performed to try to understand and to propose new strategies for this synergy in Brazil. Vilanova and Balestieri (2015) evaluated the electricity use for the water production and supply in Brazil. Five categories of indicators were proposed, that is, per capita, water losses, energy, greenhouse gases (GHGs) and financial/economic, which were used in the definition of municipal average values. As a result, they found out that the NE Region is the one that presents the greatest potential for the application of hydraulic and energy efficiency measures in water supply systems.

But above all, they are not sufficient to help to build policies for this sector. Research on the nexus of WEF resources and their impact on the Earth system is critical if we want to provide affordable and reliable resources in an environmentally sustainable way. A variety of new science programs are designed to address these nexus issues within the context of climate and the Earth system (Al-Ansari, 2015).

CONCLUSION

This study attempted to analyze the connection between water, energy and food nexus security in Brazil with an exploratory and statistical approach. The period of study was between 2000 and 2013, the variables considered were access to improved water, access to electricity and average protein supply.

Through this data, it was expected to determine the quantitative explanation of the nexus approach. With such explanatory variables, it will be possible to look for information who can lead to their status.

Consequently, statistical analyses were possible to deal with descriptive statistics. After ensuring the normality of the date was possible to perform the correlation analyzes. These analyzes showed that the three variables are strongly correlated.

Although these three data can be a small picture in the whole country, this study shows that it was sufficient to perform relations. As a future research, it is suggested to study how to implement more indicators considering other Brazilians perspectives.

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