

5th International Conference on Energy and Environment Research, ICEER 2018

Measuring the Water-Energy-Food Nexus: The Case of Latin America and the Caribbean Region

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Abstract

The Water-Energy-Food Nexus (or WEF Nexus) is a conceptual framework for analysing and managing natural resources for life and sustainable development. It is well known that to produce food, water and energy are needed; to pump, treat or purify water, energy is needed; and energy production requires water. Under this statement, this paper presents an actual overview of the current state of the water-energy-food nexus in Latin American and The Caribbean countries. The analysis is divided in terms of water, energy and food production for each country. The proposed WEF Nexus index comprises three key indicators per sector, considering availability, access, and stability of sector's resources. The obtained results show that three sectors need more attention for future development, especially in the Caribbean countries.

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Selection and peer-review under responsibility of the scientific committee of the 5th International Conference on Energy and Environment Research, ICEER 2018.

Keywords: Water-Energy-Food Nexus; Index; Sustainability; Latin America and the Caribbean

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1. Introduction

In a hyper-connected world, water, energy and food are essential and interrelated resources for life and for the sustainable development of our countries [1-4]. Water is used to produce food; almost 70% of water extraction and 30% of energy production is used for crop production; water extraction, collection, and transportation consume high

amounts of energy, and water is indispensable for energy and agricultural production [5, 6]. From this, it has been deduced that there is a need for integration of water, energy and food in governance and resource management.

Usually, the performance of water, energy and agriculture sector of a country is evaluated separately. The World Bank and United Nations among other institutions provide a number of indicators for each country and region. These indicators, however, provide only a partial view of sector's resources and prevent an understanding of the interrelationship between the sectors. The combined evaluation of the three sectors, based on available quantitative information, is vital to understand the state of sustainable development of a country or region. Recently, Simpson and Berchner (2017) proposed an approach to jointly evaluate water, energy, and food using an index that includes country's sustainability level in terms of a sector and nation's population's vulnerability in terms of that resource in the WEF nexus [7].

In order to obtain a more appropriate picture about WEF Nexus, we propose an alternative index that comprises three key indicators per sector, namely availability, access and stability of sector's resources. With these indicators, it is possible to glimpse the status of each sector regarding its resources and to obtain a general picture about the WEF nexus at a selected scale. It also could help to evaluate progress in sustainable development at city, country, subregional or regional level over the years, as well as to compare between them. As an example, we apply the index to countries from the Latin America and the Caribbean (LAC) region.

2. Description of Latin America and the Caribbean region

LAC region comprises 21 main countries in America with an aerial extension of 20 million km² located between Mexico and the southernmost tip of South America, known as Tierra de Fuego. The climate of this region is very diverse. It ranges from the hot and humid Amazon River basin to the dry and desert-like conditions of northern Mexico and southern Chile. Likewise, the vegetation varies from rain forests to grasslands and desert scrub.

The projected LAC population for July 2018 is 652 million inhabitants. The annual population growth is in the order of 1%, this is, every month the equivalent of a city of 550,000 people is added [2]. LAC region counts on the most urbanizing regions worldwide. The share of the rural population has reduced between 2000 and 2015 from 25 to 20% [8]. For 2017 the combined Gross Domestic Product (GDP) was estimated 5.4 billion USD. With a share of 8.7% of world's population, LAC countries are accountable for 6.9% of the nominal world GDP [9]. Latin America is an export-based economy, where the main exports are agricultural products and natural resources such as copper, iron, and petroleum. The income distribution among these countries is very heterogeneous. For example, the largest three economies, namely Brazil, Mexico, and Argentina represent 40%, 18% and 12% of the total, respectively, which makes up approximately 70% of the region. The human development index for LAC is among the highest in the developing regions. However, its income distribution continues to be the most unequal worldwide [10].

3. Methodology

A diagram is proposed for an efficient assessment of WEF nexus. It uses three key indicators per sector, considering availability, access, and stability of sector's resources. The indicators are mostly based on the three sustainability development goals (SDG): SDG 2 (Zero hunger), SDG 6 (Clean water and sanitation for all), and SDG 7 (Affordable and clean energy). All parameters are presented as a percentage, where 100% represents the best performance of the respective parameter, and the average of all parameters composes the index. In consequence, an index close to 1 (100%) should be the aspirational nexus goal of a country or subregion.

The selected parameters for availability, access, and stability of water resources include: water scarcity (termed W1), that is, the renewable internal freshwater resources per capita in relation to water scarcity threshold of 1700 m³/person/year. water access (W2), that is, share of the population with access to improved water source. Sustainable water use (W3), that is, revenue water calculated as the opposite of non-revenue water.

The selected parameters for availability, access and stability of energy are: renewable electricity share of total electricity output (E1); share of total population with access to electricity (E2); and energy intensity level of primary energy (E3), where 15 and 2 MJ/\$2011 GDP (purchasing power parity) represent lowest (0%) and highest possible efficiency (100%), respectively.

The selected parameters for food availability, access and stability are: average dietary energy supply adequacy (F1), this is the dietary energy supply of calories as a percentage of the average dietary energy requirement estimated by FAO. For the population; non-prevalence of undernourishment (F2), that is, the share of non-undernourished people in relation to total population; and cereal import independency ratio (F3), that is, the food supply of cereals from country's own production in relation to imported cereals.

4. Results and Discussion

4.1 Sector-wise analysis

LAC region is one of the most prolific regions in terms of water resources. It is home to one-third of world's total runoff [11, 12]). The regional data contrasts with the numbers which evidence that an important part of the region suffers water scarcity. The irregular spatial and temporal distribution of water, water quality problems and asymmetrical occupation of land versus water availability are responsible for this situation. According to FAO, in LAC region 72% of water withdrawal is used for agriculture (irrigation and livestock), 17% for municipality use and 11% for the industry. Average municipal water withdrawal in 2015 was high in comparison to other regions, i.e. 268 l/day [12]. Regarding drinking water service, LAC region is doing relatively better than other developing regions. However, twenty-five million people, living mostly in rural areas, still lack a basic drinking water service.

In terms of electricity, the LAC population had practically full access (97%) to the 1,588 billion kilowatt-hours (6.7% of the world) produced in the region in 2015. Of these, 46.5% are derived from hydropower plants, 45% from thermal power plants (namely, 26.0% from natural gas, 10.6% from oil, 6.5% from coal, and 1.9% from nuclear power), 6.4% from renewable sources such as geothermal, solar and wind, and 2.1% from other sources [8]. These numbers show that the regions' share of hydropower plants to electricity production is remarkably high in comparison to other regions, while the dependency on coal and renewable energy sources is relatively low. In comparison with other continents, LAC region has one of the greenest energy matrices if the high share of renewable energy derived from hydropower plants, wind power, and biofuels is considered [13]. Region's electricity supply expanded more than 800% during the past four decades. The share of fossil fuel generation remained constant. Gas-fired generation overtook the lead as the largest fossil source. Renewable energy sources have grown importantly, but a share of 0.9% of total power generation it is still low.

LAC region is a net exporter of food and produces sufficient for its caloric diet. During the last decades, agricultural production has increased faster than the population in LAC region. It responded not only to an increased national use but also to global food markets. The regional production is largely driven by Brazil, Argentina, and Mexico, which together account for 80% of production [14]. While the productive capacity of the region and its contribution to global production is undeniable, compared to other regions in terms of yields, LAC still has room for growth in agricultural terms, since its production yields remain low when compared to the main production regions of the world. This is particularly the case of cereals [14]. On the other hand, with nearly half of the aerial extension being forests, this region still has a huge potential for agricultural growth. The region suffers structural and cyclical constraints on access to food, which complicates the food and nutrition security [15]. Concerns of instability are the impact of climate change (droughts and floods) and the inefficient food use and management vis-à-vis increasing demand for food, environmental and social concerns.

4.2 Joint measuring and analysis of WEF Nexus

The diagram for evaluation of LAC countries is shown in Fig. 1. The Caribbean and Central American countries are evaluated as subregions. The WEF Nexus index of a country is calculated as the average of all nine indicators. The WEF index for Uruguay (0.96), Brazil (0.93) and Paraguay (0.92) are the highest, while for Caribbean (0.63), Venezuela (0.79) and Central America (0.79) are the lowest in the region. As expected, the region is highly gifted with water resources and a large portion of the population has access to water and electricity. The region is also self-sufficient in terms of food availability. All countries demonstrate an excess of dietary supply adequacy, which at the same time demonstrates the inefficiency of the food sector.

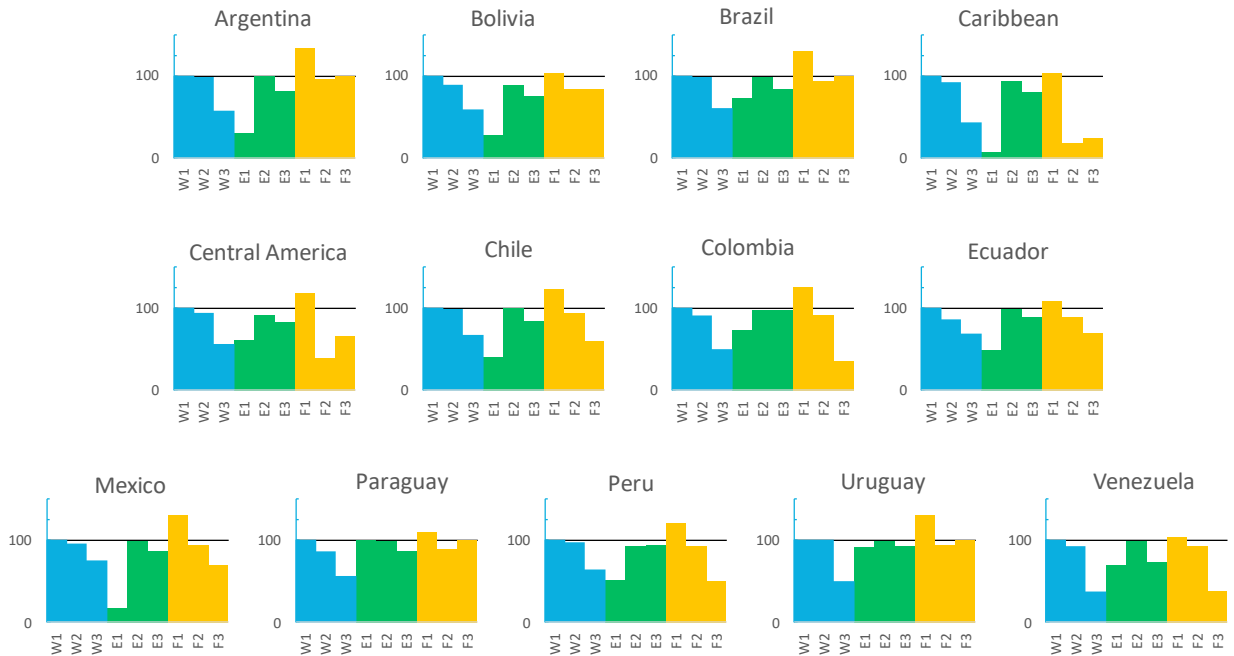


Fig. 1. WEF nexus diagrams for LAC countries. Caribbean and Central America countries are merged and evaluated as subregions. Note: W1, W2, and W3 are the indicators for water, E1, E2 and E3 are the indicators selected for the energy sector, and F1, F2 and F3 are the indicators representing the food sector. Values in percent.

The prevalence of undernourishment is relatively low in comparison to other developing regions, with the exception of the Caribbean and Central America. The cereal import dependency is relatively high in the Caribbean (74%), Colombia (64%) and Venezuela (62%), while countries like Argentina, Brazil, Paraguay and Uruguay cover its food supply of cereals completely by their own production. The revenue water of water utilities of the region was in the order of 57%. This means that nearly half of the produced water vanished due to real losses along transmission mains, storage facilities, distribution mains or service connections, as well as due to apparent losses such as water theft and metering inaccuracies, and unbilled authorized consumptions. The low revenue water is detrimental to the financial viability of water utilities but also to the quality of water and energy consumption. As a reference, most efficient water utilities in the world have a revenue water share of 93%. Regarding the energy sector, it is observed that with the exception of some countries (Paraguay, Uruguay, Colombia, and Brazil), the share of renewables (including hydroelectricity) in electricity production is low, i.e. 40% in the average. This confirms that the energy sector of the region is facing important challenges in the future because coal and liquid-fired generation is expected to reduce, while countries like Mexico and Brazil will grow fast in energy demand.

5. Conclusions

During the last years, the WEF Nexus has gained attention among academic and policy sectors. This concept is focused on the interrelationship between water, energy and food resources. There is a need to integrate these three sectors in governance and resources management and to measure the progress made in sustainable development. This paper proposes a WEF Nexus index that comprises three key indicators per sector, considering availability, access, and stability of sector's resources. These key indicators are based mostly on the three sustainability development goals of zero hunger (SDG 2), clean water and sanitation for all (SDG 6) and affordable and clean energy (SDG 7). The WEF Nexus index is applied to countries in the LAC region. This region is one of the most prolific in terms of water

resources and electricity. The share of hydropower energy is remarkably high in comparison to other regions, owning one of the greenest energy matrices. However, both the water and energy sector show asymmetries and contrasts. While the region's food production capacity and its contribution to global production are undeniable, there is still room for improving use efficiency and reducing instability provided by the impact of climate change. The WEF Nexus index elucidates differences among LAC countries and subregions. It demonstrates also a differentiated picture of the energy sector. In general, it shows that the resources sectors need more attention for future WEF Nexus development, especially in the Caribbean countries.

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