The Water-Energy-Food Nexus in Latin America and the Caribbean: Priority Interconnections

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Abstract

This paper analyzes the water-energy-food (WEF) nexus in Latin America and the Caribbean. By briefly describing the interconnections, we identify and discuss those which may prove critical for nexus implementation in the region. The interconnections that should be prioritized include: agriculture and food; irrigation modernization and aquifer overexploitation; hydropower, oil and mining; water and sanitation services and biofuels. We conclude that planning and legal frameworks play a key role in integrating and putting these interconnections and priorities into practice while WEF nexus approach could help transform the current regional development model of intensive, yet unsustainable use of natural resources.

Key words: water, energy, food, WEF nexus, planning, LAC, priorities

Introduction

Scant consideration has so far been given to the water-energy-food nexus in Latin American and Caribbean (LAC) countries, where the nexus has not been incorporated into the design of policies, plans or management of natural resources. The relative abundance of natural resources coupled with own restrictions on their underdeveloped status and a focus on pressing short-term needs have led to the nexus not being considered in intensive development models dependent on the exploitation of natural resources that have shown clear signs of environmental unsustainability and social inequality. Consequently, some of the region's characteristics, such as the relative wealth of these resources with huge potential for future development, weak governance and hardly any capacity to establish and implement public policies, alongside high levels of inequality and dissatisfaction in guaranteeing and realizing human rights, show the potential for appropriate consideration of the nexus for future improvement.

In this context, this paper seeks to identify the interconnections that can be considered priority or critical for nexus implementation in LAC. This definition is based on the following criteria: i) considering water as a predominant element; ii) impact on the other nexus elements; iii) focus on sectors of economic relevance with development potential and increasing complexity; and iv) realizing and respecting human rights, in particular economic, social and cultural rights, as an obligation and priority objective for the region's sustainable development. For an interconnection to be a priority or highly relevant, it must be a critical activity for the region or some of its countries and present an opportunity to improve its performance from a nexus viewpoint.

A. Interrelations between water and energy

Water use for energy production represents the critical element of the water-energy nexus. This is proved by 15% of worldwide water abstraction being allocated to energy production (IRENA, 2015). Such a significant figure obviously merits clarification, since it is far less in desert or arid areas where water is scarce, but, on the contrary, far more where water abounds, which is the general case in many countries in the region where hydropower predominates and its appreciable potential still needs to be tapped into.

The generation of hydroelectricity is currently by far the main source of power in the region, but it is distributed very unevenly among the countries. The Southern Cone produces 68% of its electricity by hydroelectric means, while in the Andean Community of countries, this percentage rises to 71%. In Central America, Mexico produces 15% of its national electricity production by hydroelectric means; however, all the other countries produce a higher proportion of their electricity with this source, led by Costa Rica with 78%. The Caribbean countries are the exception since they do not depend on hydropower as they do not have much surface water (Escobar, López & Clark, 2011).

South America is the third region worldwide that added the most hydropower capacity in 2015 (IHA, 2016). At the same time, hydroelectric projects come second, after mining and oil, in causing social unrest due to the use of water resources (Martín & Justo, 2015). These data suffice to demonstrate that hydroelectricity production is and will be one of the key nexus interactions in the region. With this potential and growth rate, this sector provides an opportunity to apply a nexus focus combining the multipurpose nature of reservoirs more efficiently with optimization of their economic, social and environmental impact.

Regional hydroelectric potential must be re-evaluated from a nexus and trinomial planning focus, as must hydropower projects in the design, construction and development phases, based on future scenarios of flow rates, precipitation and water use, since more installed capacity does not necessarily mean more generation. Instead of static plans and designs, hydroelectric infrastructure should be planned within the ranges of uncertainty imposed by climate and precipitation trends. Consequently, the recommendation is for plans to contain provisions for specific operations depending on the climate and demand for water, based on a flexible infrastructure and pumped-storage plants and smaller hydroelectric systems must be considered as options to overcome this climatic variability (Escobar, López & Clark, 2011).

Hydroelectricity production gives the system reliability, but it must be complemented by other forms of renewable energy, even if they are intermittent, to reduce the risks from depending excessively and exclusively on the hydroelectric source. Permanent or seasonal changes or decreases in generation due to drought or reduced flow rates prove that the situation is worsening in some regions, countries or catchment areas with the prediction of future scenarios (Vallejo, 2013; Flavin et al., 2014; Recalde, 2016; CAF, 2016).

The obviously priority production of hydrocarbons and mining can also fall within the interaction between water and energy, as it uses both, due to reasons that include the extreme dependence of many countries in the region on these activities and proven reserves (Altomonte & Sanchez, 2016). This is the case of the Andean countries (Chile, Bolivia, Peru and Ecuador) and others, such as Argentina, Brazil, Colombia, Mexico and Venezuela. Water consumption in mining in Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico and Peru can account for up to 6% of all water use (Willaarts, Garrido & Llamas, 2014). Although detailed and reliable information is lacking on the impacts these activities cause on nexus elements, the implications of both hydrocarbon exploitation and (formal and informal) metal and non-metal mining in nexus terms are relevant to the extent that they unlawfully occupy the first level in terms of potential for social conflict (Martín & Justo, 2015).

One example within this group of recently developed activities that should be nexus focused is the exploitation of non-conventional hydrocarbons. The investigation and exploitation involved in the hydraulic fracturing process have far higher energy, water and environmental impacts than the methods used for conventional resources. The region has more than a quarter of total worldwide technically recoverable natural shale gas resources, mostly located in Argentina, Mexico and Brazil, which are in a full exploitation phase (Arroyo & Perdriel, 2015). The main risk of exploiting shale affects water, the key nexus element, while its essential role for the region is explained by: i) possible self-supply of energy in countries that have this resource; ii) possible economic impact of lower power prices, less volatility in these prices, more economic growth, fewer inequality levels, generation of employment sources, and so on; and iii) possible strengthening of energy integration in updated regional geopolitics.

B. Interrelations between energy and water

Concerning the relationship between energy and water, the first point worth mentioning is the essential role energy plays in the more ‘traditional’ techniques of seawater desalination, debrining of brackish water, pumping of groundwater and irrigation modernization, making it possible for these processes to take place. Although desalination is not generally a priority in the region, it is beginning to become an increasingly attractive option, especially where there are no alternatives, as in the Caribbean (Hoff, 2011), or in arid locations, to perform high-profitability activities, such as copper mining in Chile or urban use in Mexico.

A recent study on Chile using a particular conceptual focus of the nexus in four regions in the country with a variety of problems (Antofagasta, Copiapó, Maipo and Maule) confirms several of the interactions identified as priority in this study for the region—mining, aquifer overexploitation, urban expansion, hydroelectricity and agriculture—and

concludes that reuse, recycling and desalination are becoming attractive management options in some arid and highly vulnerable areas (Meza et al., 2015). But its impacts and negative externalities must be well explained and understood by decision-makers, private managers and society to coordinate and define adaptation policies and strategies aimed at consolidating the nexus.

Highlighted in this interconnected scenario are drinking water and sanitation services in regards to the expansion of their coverage and, especially, the improvement of their quality and the increase in municipal wastewater treatment for agriculture involving electro-intensive activities that are often inefficient. It is estimated that a significant proportion of the energy consumption of water supply and sanitation services occurs in the conveyance and distribution or collection phases, particularly the pumping of fluids in the drinking water supply. In contrast, in the sanitation system, electricity is most consumed in wastewater treatment. Sludge treatment and disposal represents significant consumption, although it can also generate energy (Ferro & Lentini, 2015). The electricity costs of drinking water and sanitation system providers represent 5–30% of total operating costs and it is estimated that the total energy cost can be reduced by 5–15%.

Long-distance interbasin transfers require the use of extremely high amounts of energy for the conveyance (including lifting). In some places in the region (for example Mexico City, San Pablo in Brazil) this is important even when these lifts can often be compensated by drops in the conveyed water and the possibility of installing hydropower plants in these sections. The above relationship is very important due to constant growth in energy consumption in the above-mentioned processes. This is related to resorting to desalination once technical advances have led to a substantial drop in the cost of desalted water, which, in any event, is still far more than the cost of water collected by other means. The same can be said of the increased use of groundwater in agriculture, especially when the price of energy is subsidized in several countries. In view of high energy consumption, the main proposals comprise more use of renewable energy and an increase in energy efficiency (Ferro & Lentini, 2015).

The central place agriculture represents in the region is obvious: it uses around 80% of the water and occupies 25% of the total surface area. At the same time, there is considerable potential for expansion and possibilities to increase productivity associated, above all, with the implementation and modernization of irrigation, which, in most cases, is linked to an increase in energy consumption. Irrigation modernization and expansion and the increasing use of and dependence on groundwater form a relevant variable in some of the region's countries and could become critical for the nexus in many others in the future.

We conclude that irrigation expansion and modernization, and aquifer overexploitation are the priority interconnection in this area. A more intensive or efficient use of water in agriculture involves an increase in energy consumption, which must be previously addressed using a trinomial focus. Modernizing irrigation without appropriate consideration of the hydrological, environmental or energy impacts in regions with an energy deficit, supply insecurity or price volatility can further producer vulnerability and increase their costs with the subsequent impact on agriculture and livestock production and its profitability and the future demand for subsidies from the public sector. These are

factors that must be considered in the design of a nexus-focused policy for a sector that offers major implementation and expansion opportunities.

The overexploitation of some aquifers involves a series of problems and inefficiencies that could be modulated or prevented using a nexus focus. With low energy prices that are often subsidized to promote agricultural development, the overexploitation of aquifers can lead not only to a non-sustainable management of aquifers in hydrological and environmental terms with significant impacts on quality and quantity, but also energy inefficiency and, in some cases, social injustice. Inefficiency stems from the higher energy cost of pumping, both on a global and individual scale, which increases as water-table levels drop. Also worth considering is the injustice for the losers in the re-entry race, higher costs of extraction or use of electrical subsidies designed by policies that do not generally segment beneficiaries and end up favoring the major players, even to the detriment of priority uses, such as a municipal water supply as opposed to agriculture or mining. The unbridled race for re-entry drilling in overexploited aquifers often complicates municipal supply and human consumption due to the decrease in levels or quality, emphasizing its high individual and social cost on the one hand and no or weak controls in the land characterizing the region on the other. Examples of this situation can be found in Copiapó and Antofagasta (Chile), Valle de Ica (Peru), Guanajuato, Sonora, Mexico City and Mexico where it has received particular attention (Scott, 2011).

C. Interrelations between water and food

The relationship between water and food can be considered in the rural environment, where it refers to agriculture either with or without irrigation, and in the urban environment, where it is mainly linked to the provision of public drinking water and sanitation services, the supply of food to cities and waste management. Firstly, connections are established using water for two coincident purposes in food production: irrigation and aquaculture, with far more importance placed on the former than the latter. Water use percentages in this area compared with other sectors can vary depending on the country, but they are around 70–80% and perhaps even 80–90% (Hoff, 2011). This is the most important use and consumption since returns to the cycle do not usually exceed 20–30% in plot irrigation, even when much higher losses occur in the conveyance to the plot when the channels are not lined. Similarly, irrigation enjoys a privileged position in countries whose legislation is based on a hierarchy of uses, normally only exceeded by the municipal water supply.

Above all, the prime aim is to achieve maximum effectiveness from existing irrigated land. In general, irrigation efficiency in the region is not very good, an issue often primarily determined by water conveyance infrastructures, which are not always lined to prevent leaks. This type of action requires a sufficient quantity and quality of water to be available, the financial means for the investments and then, an aspect that is often overlooked, also have appropriate organizational structures to effectively and productively manage this increase in irrigated agricultural land. Some of the conditions also required are an administration with appropriate technical levels to attribute with legal certainty the necessary water flow rates (by means of concessions or other systems) to address this new irrigated surface area, and a registry of public water that provides an exact picture of

the legal water distribution and use situation. This is extremely hard to find and often compromises the success of public policies.

To prevent some of the risks involved with irrigation, emphasis is sometimes placed on more capacity to improve food production with 'green water', which comes from rain, is in the ground and is linked to non-irrigated crops, in contrast to 'blue water', which is artificially conveyed by various channel types and leads to irrigated crops. The argument is that where there is not enough water, improvements can only be made by increasing the productivity of existing water and limiting population growth, which will lead to food security (Falkenmark & Rockström, 2011). The relationship can also improve with an increase in municipal wastewater treatment reaching quality levels that enable its use for irrigation. This is feasible near large inhabited population centers where the costs of wastewater treatment and regeneration facilities can be defrayed. Rainfall harvesting, in other words collecting precipitation, has a role to play in this relationship.

No exploration of the water-food relationship for the purposes of the nexus can ignore the possibilities virtual water trade offers, since LAC region has shown to be a net exporter of virtual water, quantitatively important in the cases of Argentina and Brazil (Willaarts, Garrido & Llamas, 2014).

However, despite an extraordinary potential in water and energy resources and food production capacity, in most of the countries the region still owes its own population a huge debt where food is concerned (Martínez & Palma, 2016). The potential implementation of a nexus focus cannot sidestep that it is not the food, the water resources, the energy sources or the agricultural development that is lacking in the region, but rather a minimal equity in sustainable development models and their distribution, as posited by some nexus focuses (Biggs et al., 2015). It follows, therefore, that agriculture is not directly equivalent to food nor to feed.

This paradox highlights the need to complement and connect the new nexus concern and water-food-energy security with the satisfaction of basic human rights required by the legal system and closely linked the nexus elements, in particular the right to food being indiscernible from the right to water. If the situation is examined from a security point of view, the paradox can be seen in the key role the region has been given in ensuring global food security (Bellfield, 2015) while it seems incapable of guaranteeing minimum acceptable security levels in the three elements for itself.

One aspect that has better links to food security, generating employment and reducing poverty, and more potential to improve them—observed cross-sectionally in all the countries of the region and which characterizes as a production method—is family agriculture. This form of economic organization coexists in the region with the medium-sized and large enterprises, but it has been undervalued by governments and society.

The urban water cycle or urban nexus should also be mentioned at this point. It includes conveyance from the supply point, drinking water treatment, conveyance of treated drinking water, collection of wastewater, conduits to the associated wastewater treatment plants, wastewater treatment, sludge treatment and, ideally, the regeneration of urban wastewater so that it can be reused with suitable quality levels for a variety of purposes including agriculture.

Based on the above considerations, we can conclude that drinking water and sanitation services are also priority interconnections. This interconnection has become highly important in the region for several reasons, including the following: i) 80% of the population is urban with forecasts for more increases; ii) current urban expansion has hardly been planned; iii) the existence of several megacities or large urban conglomerates as critical spaces for urban supplies and increasing energy costs; iv) the lack of sustainability, vulnerability and spatial segregation; and v) the deficient and low coverage of public services, in particularly sanitation and treatment systems (CEPAL, 2014). This phenomenon, which clearly characterizes the region as having one of the highest urban population percentages worldwide, represents a cross-sectional problem as it involves the three nexus elements with specific interactions in urban contexts in developing countries in general (Babette, 2016) and Latin American megacities in particular.

D. Interrelations between water, energy and food

The best example of the trilateral relationship might be biomass production using plant products considered as a source of energy. The growth of this phenomenon has been substantial in recent years in some geographical areas, especially in the region (Saulino, 2011; Hoff, 2011). However, the positive elements of a new energy source classified as 'renewable' need to be clarified given that this production of plants to generate energy can involve a decrease in food production (resulting from the associated reduction in agricultural land for that purpose) and also remove some of the water linked to irrigated agriculture. If the biomass is forest waste, the ecological function of the forests can be affected. Another consequence can be an increase in food prices, although the cause–effect relationship between biomass production (worldwide) and agricultural prices is not unanimously accepted (Martín Mateo, 2008).

These risks can be prevented with appropriate public intervention, which can operate on several levels. The first is the authorization of energy production facilities with this origin. Another is the intervention that can take place on agricultural or forest land that has been earmarked for these purposes. Normally both intervention types are necessary. At the 2011 Bonn conference, a preventive approach was outlined to the effect that 'developing countries considering bioenergy must weigh up every factor and consequence, such as land suitability, water availability, competitiveness, socio-economic costs and benefits, food security, economic growth and poverty alleviation' (Hoff, 2011).

The region is a net exporter of raw materials and food with a huge potential still for more development. In particular, Brazil and Argentina are among the major biofuel producers, although other countries, such as Colombia, Paraguay and Peru, are producers to a lesser extent. Nevertheless, some countries like Bolivia are moving in the opposite direction banning biofuels.

In the cases of Brazil and Argentina the production of these biofuels has greatly increased, as has their consumption, with a relationship between production and consumption level and the price of oil. The result of this production activity is a huge increase in water demand, an increase that is less in Brazil than in Argentina, since sugarcane is not irrigated in Brazil but it is in Tucumán (Argentina), where the most production is concentrated. In both cases, however, water pollution has risen due to the use of fertilizers and pesticides in the production process of plants and similarly, pollution

has increased in the water arising from the biofuel production process (Saulino, 2011). Out of the food-energy interactions, biofuel production is especially relevant for the region (Mirzabaev et al., 2015). From this perspective, the nexus focus involves the need to revise the conditions in which some countries' commitment to producing biofuels has occurred (Saulino, 2011; Scott, Kurian & Wescoat, 2015).

Conclusions

Unlike previous considerations, the nexus focus examines the multiple interactions of the three elements to define priorities and avoid harmful or undesired effects, with environmental protection always in the background. Out of the activities involving two or more nexus elements, considering the following is obviously a priority for the region:

a) Water-energy: hydropower, hydrocarbons and mining

Most energy production methods require water, although hydroelectricity is the most important method in the region as the main source of power offering most future growth in the majority of South and Central American countries. Large-scale hydropower demonstrates multiple interconnections and excessive dependence on this source, considering climate change and variability, simultaneously threatens water, energy and food security in countries such as Colombia, Venezuela and some in the Caribbean.

The exploitation of hydrocarbons and mining demands variable quantities of water and energy, which can seriously affect the environment and the quality of water resources. This interconnection is highly relevant throughout almost the entire region, but very especially in the Andean countries, Brazil, Mexico, Venezuela and some in Central America. The relationship could become especially intense when hydraulic fracturing techniques are used. The use of water for energy does not compare with water use for agriculture in quantity (except in arid or semiarid regions), but it is the use that causes the most social unrest due to the displacement of people, its associated consequences and the impact on the sources quality.

b) Energy-water: Water abstraction, use and desalination

The largest energy cost in relation to water in the region occurs in the abstraction stages of groundwater, conveyance and use, which include irrigation. This interconnection must especially consider the subsidy level for extraction, aquifer overexploitation and the inefficiency of irrigation systems and pumping equipment. The relevance of groundwater and growing dependence on it are shared throughout the region with an emphasis on Central America and Mexico, where it amounts to 65% of consumed water and in the desert or semidesert areas of Argentina, Brazil, Chile, Bolivia, Mexico and Peru. The increasing overexploitation of aquifers presents interrelations with the three nexus elements by impacting water quantity and quality, removing land from production and increasing the energy costs of extracting it. Currently, energy consumption is not significant in water treatment or seawater desalination, which are confined to isolated areas for highly profitable activities (mainly in Chile, Mexico, Peru and some Caribbean countries).

c) Water-food: Agriculture

The importance of agriculture must be understood in relation to regional peculiarities where large-scale practice and expansion, mainly for exporting, have a direct relationship with deforestation, single crop growing, the subsequent increase in the risk of diffuse pollution, sedimentation, erosion and flooding, the displacement of the local population and the impact of family or subsistence agriculture, essential for food in the region. Its relevance is key for the region in terms of water consumption, participation in the gross domestic product, and employment forecasts and it affects almost all the countries in the region.

d) Water-energy-food: biofuels and irrigation modernization

A special link occurs between the three nexus elements in cases of biofuel production given that they usually consume water, are used to produce energy and can affect food production due to removal. Agriculture for energy production or biofuels not only share the impacts of large-scale agriculture referred to above, but also have a considerable effect on food availability and price. The development of biofuels is particularly relevant in Argentina, Brazil, Paraguay and, to a lesser extent, Peru, Colombia and Central American countries, such as Costa Rica. The relationship between the three elements can also be observed in the agricultural sector when irrigation modernization is involved (which leads to more energy use, more water consumption and could increase food production) or policies are established to promote electricity, fostering aquifer overexploitation, based on discounted tariffs, given that water abstraction increases.

Although this summary is not exhaustive, it synthesizes the priority nexus interactions that are crucial for most of the region's countries. When considered in public policy planning and adoption, they can help prevent proven harmful effects and instead extract all the advantages and potential the focus entails.

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