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MANAGEMENT OF NATURAL RESOURCES FROM NEXUS PERSPECTIVE: CASE OF STUDY IN CEARA, BRAZIL

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Abstract

The Nexus approach seeks to consider the connections between water, energy and food at local, regional and global level. This study proposes to explore some characteristics and synergies of local ecosystems and possible interventions in order to develop a generalist local water, energy and food Nexus model for the effective and sustainable management of natural resources and treatment of the waste. The methodology was built in four stages: (i) elaboration and application of questionnaires to survey the water and energy demands and to understand the eating habits of the actors under study; (ii) analysis of soil quality in the laboratory in order to verify the need to use fertilizers and treatments to recover degraded areas; (iii) proposing alternatives for water supply, energy and food production; and (iv) elaboration of the local Nexus model. The proposed alternatives integrate the elements of the model. Among them are the use of solar panels, the use of cisterns, composting, biodigester, evapotranspiration basin, artisanal fish farming and permaculture design. Considering the inputs and outputs of each element it was found that all of them are dependent on water supply except for solar panels. Based on the model's interconnections, a new structural design for the study area was proposed to contribute to the development and applicability of the Nexus approach at the local level.

Keywords: environmental security, sustainable development, natural resources.

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Introduction

The global demand for water, energy and food has been following a rapid growth, characterized by intense urbanization, demographic explosion and great geographical disparity. Pollution and depletion of drinking water sources along with soil degradation and desertification occur in parallel. However, climate change is a key point of impacts in the medium and long term.

According to Nexus approach, to meet the demand of the growing world population, especially in developing countries, it is necessary to consider water, energy and food production in an integrated manner, as each of these domains has direct interference in the others. For example, poor access to sources of treated water and energy can reduce the food supply, while power generation depends on water sources while water treatment and supply depends, in turn, on reliable sources of energy, as well pointed by Terrapon-Pfaff *et al.* (2018). Yet, other researchers like El Bilali (2018) stated that in face of climate change, population growth, ecosystem degradation and increasing resource scarcity, it is necessary a genuine sustainability transition to achieve sustainable food and nutrition security.

According to Zhang et al. (2018), this approach sees food, energy and water security as three essential pillars for human reproduction and interconnected in a way that, under certain circumstances, should be planned and managed integrated. Thus, this approach seeks to consider these connections in a broad and complex way, analyzing the social, economic and environmental impacts involved when it comes to planning, technological innovation and formulation of public policies. It promotes the development of assessment, planning and monitoring methods, modeling techniques and risk analysis at local, regional, and global levels.

In the international scientific literature can be found reviews of Nexus as in Albrecht, Crootof and Scott (2018); Cai et al. (2018); Bleischwitz et al. (2018); Brouwer et al. (2018); Olawuyi (2020). These reviews have addressed a rapid expansion of this concept in the academic area and the new political configurations, due to the emergence of complex challenges and the need for effective management of resources. The analysis of various proposed methods provides a knowledge base applied to implement reasonable practices in Nexus and develop better analytical and practical methods.

In Brazil, these reviews are still incipient. We can find works like Ferraço and Moraes (2019) in the scope of environmental law, while Mercure et al. (2019) discuss the significant advances in the use of this approach at the federal, state and municipal scales in the context of unprecedented pressures on Brazilian ecosystems from global environmental and economic changes.

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An unique and totalizing understanding of this approach can be seen as a difficulty, because it uses concepts, purposes and methodologies that are not yet solidly established in international doctrine and practice, and can be manipulated according to the character of the objectives that each research proposes.

On the other hand, as a methodology aimed at the management of natural resources, the challenge lies in the complexity of the relationships between subsystems and issues of public interest (Staupe-Delgado, 2019) as well as the institutional management of resources in common use.

Regarding the local level, one of the possible difficulties in applying this approach is the unavailability of data. While the Bonn conference focused on the availability of water sources on different continents (Hoff, 2011), at local or community level in developing regions it is likely that some data on precipitation, groundwater and related ecosystems do not have quantitative and qualitative data for a considerable period of time for analysis. Consequently, a quantitative analysis in these cases should not be understood merely as flows of input and output of information, but as a way of obtaining a visualization of the variables involved so that it is possible to show the tendencies of the different elements to be influenced and how they can be stimulated to generate positive results (Terrapon-Pfaff *et al*., 2018), that is the perspective adopted here.

The objective of this study is to propose a local Nexus model for the effective and sustainable management of natural resources. For this, the research identified local water, energy, and food demands through the questionnaire application on-field and alternative proposals for local water supply, basic sanitation, and energy production, as well as sustainable agricultural production. We discussed the interconnections of the elements proposed in the model in the context of the Anthropocene. Besides, we designed the methodological procedures to replicate the study to other areas so that this local Nexus model can be a tool for the planning and management of natural resources.

Study Area

The study was developed for Brotando a Emancipação Ranch, which is located in the municipality of Cascavel, state of Ceara, Brazil (Figure 1). The Critical Radical Group acquired the Ranch of 65.5 hectares in 2014, intending to break up with the “production of goods” and to establish a “new social relation not mediated by work”. If the intent is to be an experimental place that involves the local community in a search for water, food and energy emancipation, a local Nexus model serves as planning and guidance for an appropriate resource management that provides a multidisciplinary vision for sustainability.

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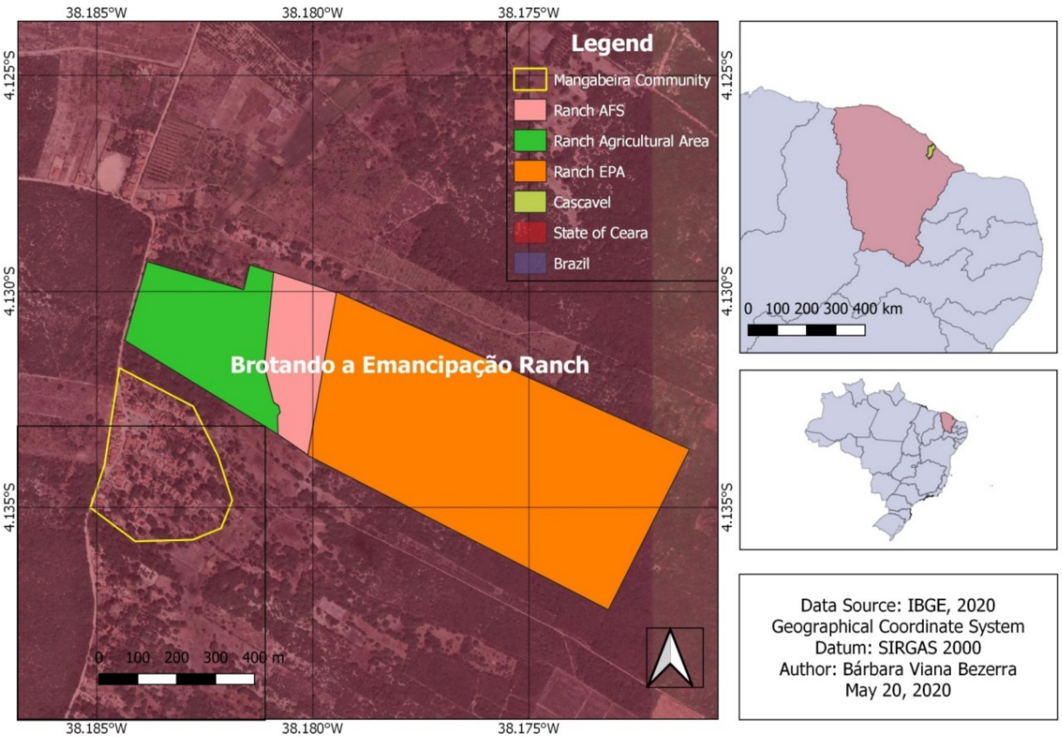

Figure 1. Location of the Brotando a Emancipação Ranch at State of Ceara, Brazil.

Currently, about five people live permanently and on weekends, it receives students, representatives of social movements, agroecology groups and organizations from other events. Also, the place seeks to meet the Mangabeira Community's demand located on its borders.

Its physical infrastructure is still incipient and, concerning water resources, is characterized by a water tank 15m high and capacity of 60m^3 of water, a well and an intermittent stream. The well is used for irrigating gardens and washing clothes. Concerning land use and occupation, the Ranch consists of three areas: Environmental Preservation Area (EPA), Agroforestry System (AFS) and Agricultural Area.

Data and Methods

In order to propose effective and sustainable management of the local natural resources of Brotando a Emancipação Ranch based on the Nexus model (water-energy-food), firstly information was obtained on the soil characteristics of the Ranch and on the water and energy demands of the Mangabeira Community, which localizes in its borders. The methodological procedures were performed as shown in Figure 2.

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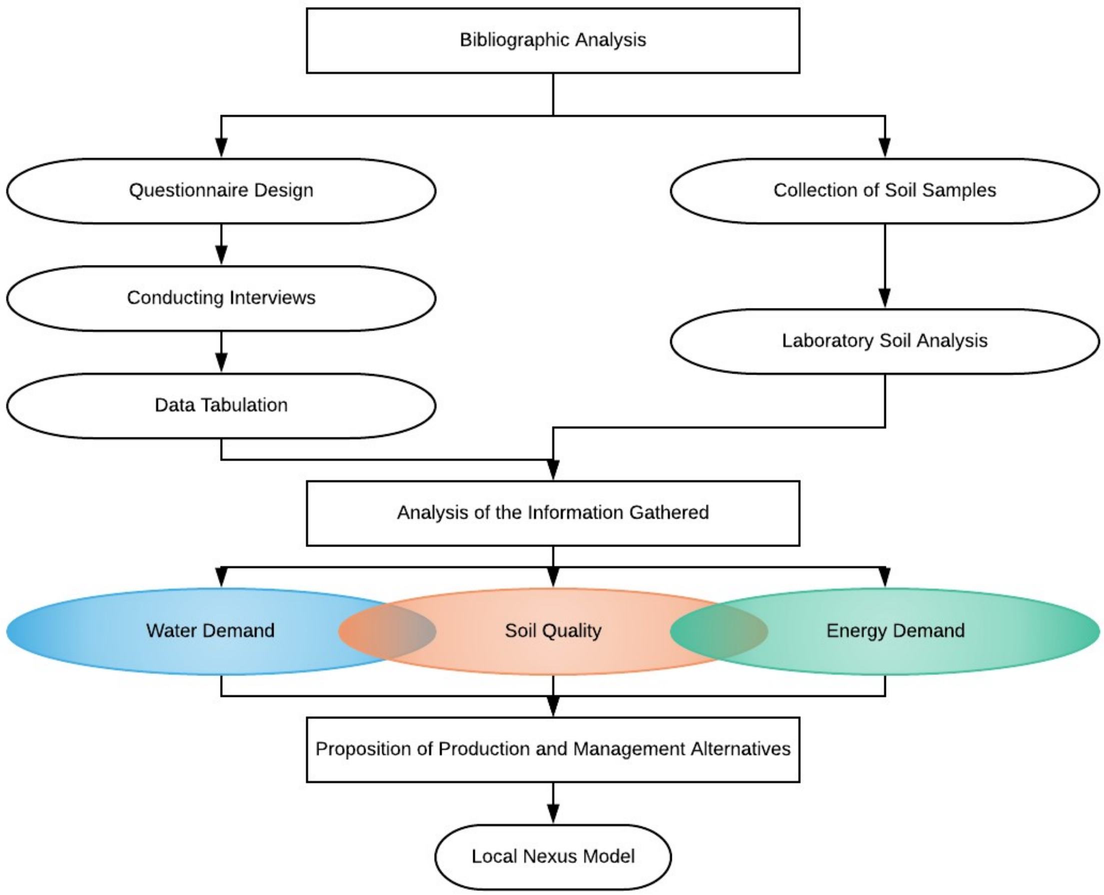

Figure 2. Methodological strategy adopted.

Data Survey

The research considered the Mangabeira Community as a user of the space proposed in this study. However, involving more the community at the transformation of the space to a more productive ranch and an experimental place to new practices of natural resources management is still required. Regarding this region of the municipality of Cascavel, the information is practically nonexistent.

Because of this, we applied a semi-structured questionnaire to understand the community's eating habits, social aspects and access to the drinking water. Also, the questionnaire was able to develop an approximate profile to constitute a basis for calculating water consumption, electricity, food, sanitation, and also possible improvements desired by local residents.

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The questionnaire consisted of fifteen questions, distributed among the following items: food, health, basic sanitation and consumption of energy and water.

We applied the "Snowball" method to conduct the interviews. We choose this method because of the inaccuracy of the total number of actors in the study, the difficulty of access to the population, and the use of this survey being only for exploratory purposes.

This method consists of a possible path for social research in the field of communities, being a form of non-probabilistic sample. It works based on the indications of the current interviewees of the survey of other possible participants and so on until the content already obtained begins to repeat itself, with no further addition of new information, that is, until a saturation point in the responses is reached. Therefore, we can characterize it as a “sampling technique that uses chains of reference, a kind of network” (Baldin and Munhoz, 2011).

According to Vinuto (2014), a limitation of snowball sampling is the possible inconvenience of accessing only similar arguments since individuals will necessarily indicate people from their network. However, to reduce the weight of this limitation, it is possible to obtain seeds from different networks, increasing the possibility of accessing different ones and, consequently, more plural narratives.

In order to reduce the bias generated by this limitation, the research objectives were clarified to all participants before the interview. Also, highlighting the different types of profiles.

We conduct surveys to understand the hydrography, relief and land uses in the study area, based on data provided by Google Earth, MapBiomas Project (Mapbiomas, 2014 - 2018), Water Resources Company from Ceará (COGERH, 2019) and TOPODATA (INPE, 2020).

Soil Quality

The Ranch´s total area is 65.5ha and the characteristic soil of Cascavel city, which encompasses both the property and Mangabeira Community, is of Dysthophic Quartz Sands (Embrapa, 2011a), classified according to the Brazilian System of Soil Classification. Its origin is sandy deposits, made up of quartz grains, with sand texture along about 2m deep. They are practically devoid of primary minerals and present little resistance to weathering.

This type of soil is considered of low agricultural capacity and needs management practices for the maintenance of organic matter and intensive care in erosion control, besides fertilization, mainly with nitrogen and potassium, and adequate irrigation. Using this soil according its agricultural suitability demands certain analysis, for example, cation exchange capacity (CTC), which evaluates the need for organic matter content and the right fertilizers. For greater

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precision of the soil quality, we carried out laboratory analyses to verify the need for fertilizers and treatments for the recovery of degraded areas or other improvements.

The soil analysis was carried out at the Soil and Water Laboratory of the Agricultural Sciences Center of the Federal University of Ceará (UFC), which has an agreement with Ceará Meteorology and Water Resources Foundation (FUNCEME).

Demand for Water and Energy

We applied the demand for electricity (Equation 1) to obtain the average consumption of the Mangabeira Community. It was estimated considering the number of households, the average number of residents per household, and the average residential consumption obtained from the Brazilian Energy Research Statistical Yearbook (EPE, 2019).

$$D_e = D \times C_{ac} \qquad \textbf{Equation (1)}$$

Where:
D_e = Energy Demand;
D = Total Number of Households;
C_{ac} = Average Residential Consumption.

We estimated the demand for water based on the number of residents in the community. The average number of residents per household was obtained through a field survey. In relation with per capita demand, the National Sanitation Information System provided this information (SNIS, 2019). It is expressed in equation 2:

$$D_w = D\ x\ \left(\frac{N°\ residents}{households}\right) x\ C_{pc} \qquad \textbf{Equation (2)}$$

Where:
D_w = Water Demand; D = Total Number of Households;
C_{pc} = Per Capita Consumption.

Besides, we also calculated energy and water demand from the field research for comparison and accuracy, as there is no data for this specific community.

Results

The interviewees were responsible for the family group, all of whom were over 18 years old. It was made an initial presentation of the research and the study area with free access for participation. Thus, we applied about 40 questionnaires between 270 households, which this data revealed information about the community´s eating habits, the water and energy demands, and the sanitary sewage.

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Water Demand and Sanitation

In Mangabeira Community, the Integrated Rural Sanitation System, Sisar Project (Sisar, 2020), which belongs to São José Program, is responsible for water supply. Water and Sewage Company of Ceará (CAGECE) created this project in 1996 to facilitate the development and maintenance of the systems in a self-sustainable way. Currently, it is present in 152 municipalities in the state, serving around 700 thousand people, constituting thousands of water connections (Sisar, 2020).

According to the ex-president of the Community Association of Residents, Mr. Edvaldo Lopes, the Municipality of Cascavel donated an area of approximately 2,156m^2 for the project installation, which consists of a deep well, water treatment system and distribution. The final amount to be paid per residence varies according to consumption. According to information provided by the official website of Sisar Project (Sisar, 2020), the consumption tariff charged in 2019 at Fortaleza unit (valid for the municipality of Cascavel and localities) was R$ 13.50 per 10,000 liters of water consumed. No household represented in the survey has a well, and only two respondents claimed to have a tank without the use of an engine.

The fixed amount charged in the community, which includes energy, system operator and administrative fees, is approximately R$ 12,00. Figure 3 shows the average water cost of families in the Mangabeira Community by percentage of households in which the questionnaires were applied.

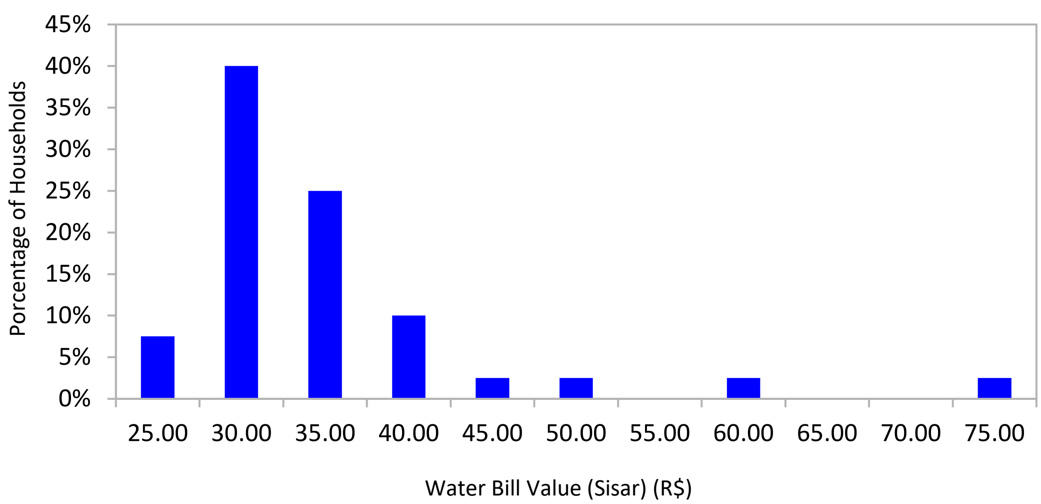

Figure 3. Average spent on water bills by residents of the Mangabeira Community by percentage of households.

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The survey of average consumption of water and drinking water per family should be considered in the planning of water management according the local Nexus model. According to Figure 5, all inputs of the model to each element, with exception of solar panels, depend on water. In addition, this resource needs to be planned for community's daily consumption by Sisar Project, wells, cisterns and rainwater harvesting, besides he assurance of correct sanitation techniques to avoid water pollution. Concerning the village's sanitation, this is done mainly through a septic tank, as found in 100% of the interviews.

According to UN information, about 110 liters of water per day for individual consumption is necessary to meet all basic needs. As obtained from data collected in 2018 by the National Sanitation Information System (SNIS, 2019), per capita consumption in Brazil corresponds to 154 liters person per day, while in the state of Ceará, it is 125 liters.

For purposes of calculating water demand, we considered SNIS provided information on the Brazilian average water demand so that all residents' needs could be satisfactorily met. Therefore, according to equation 2, and considering an average of 4 inhabitants per household, we estimated water demand at $90.55 m^3 . day^{-1}$.

Energy Demand

The actors of the study provided the amount of kWh consumed through the electricity bills. Figure 4 shows the average energy cost of families concerning the percentage of households. On average, there is an expense of R$ 74.05.

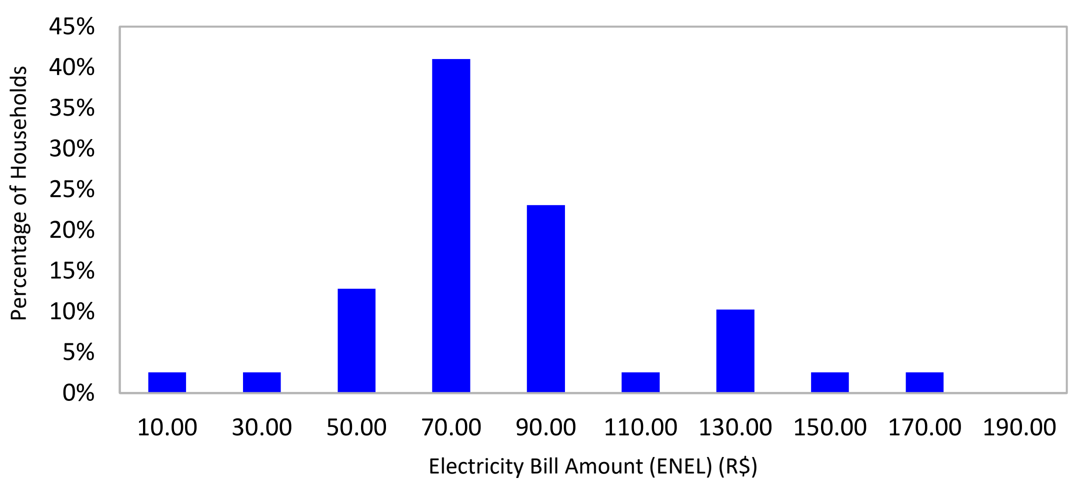

Figure 4. Average spent on electricity bills by residents of the Mangabeira Community by percentage of households.

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According to the Energy Research Company (EPE, 2019), a service provided to the Ministry of Mines and Energy, in its Statistical Yearbook for Energy Research 2019, the average residential consumption in the state of Ceará is 129.5 kWh, while annual consumption per capita in 2018 was 1,237 kWh per inhabitant.

This survey of the average energy consumption by residence in Mangabeira community is important as it will be considered for calculation of energy needs involving the ranch and the community so local energy production and supply can be planned and coupled with water management and food production. Thus, taking as a reference the average residential consumption in the Mangabeira Community, added to the monthly consumption of the Ranch, of 725 kWh, we have a monthly energy demand of approximately 27 MWh (Equation 1). If we take the national average into account, the energy demand of the community and the Ranch would be 19.8 MWh.

Considering only the demand of the community, we have an average monthly residential consumption of 178.99 kWh, that is, above the state average, which can be reduced by sustainable practices and complemented with other renewable energy sources. The amount of energy should even increase as other equipment are implemented.

Soil Quality

According to the survey of water and energy demand of the Mangabeira Community, as well as the result of the soil analysis, we proposed alternatives for management of the natural resources and production at Brotando a Emancipação Ranch.

The result of the soil analysis is shown in Table 1. The soil can be considered as having a neutral pH, low levels of organic matter, low potential acidity ($H^+ + Al^{3+}$), and high base saturation (V%), in addition to low levels of phosphorus, calcium, aluminum, magnesium, and potassium. The texture is predominantly sandy, with high porosity and permeability, facilitating the aeration of the roots and hindering the waterlogging. The granulometric composition indicates there is higher coarse sand contents, which implies lower CTC and water retention due to rapid infiltration, meaning a disadvantage which can cause dry problems.

The evaluation of acidity (exchangeable and non-exchangeable acidity) is represented by H + Al, and this relationship depends on physical, chemical and soil mineralogical composition. The amount of exchangeable bases like calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) indicates on what level of weathering the soil is. Younger soils with less weathering present higher amounts of these four elements. This influences the options of recovering, for example, lack of calcium and magnesium can be raised by application of dolomitic limestone. If only the acidity must be corrected, calcitic limestone can be used (Leão, 2018).

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Base saturation (V%) shows the proportion of cationic exchange capacity by bases and includes K and Na. Soils with base saturation greater than 70% indicate no need for liming. Considering organic matter, this is one of most important regulators of soil CTC and prevents the soil from being leached and to be permanent available to the plants.

According to Leão (2018), conservation techniques, such as sustainable management practices, with the use of no-till, crop-livestock integration, should be adopted for the sustainable use of sandy soil in agriculture crop rotation, green manure and maintenance care soil moisture and erosion processes.

Table 1. Soil analysis of Brotando a Emancipação Ranch (July 15, 2019).

Soil Analysis Result								
Horizon		Granulometric Composition (gkm^{-1})						Classification
Sample	Symbol	Depth (cm)	Coarse Sand	Thin Sand	Silt	Clay	Natural Clay	Texture
408	-	0-20	725	183	62	31	11	Sand
Degree of Flocculation	Density (gcm^{-3})		Moisture ($g\ 100g^{-1}$)			pH		C.E.
(g 100g-1)	Global	Particle	0.033 MPa	1.5 MPa	Useful Water	Water	K Cl	$dS\ m^{-1}$
64	1.46	2.69	-	-	-	8.2	-	0.06
Assortment Complex ($cmol_c/kg$)								
Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	$H^{+} + Al^{3+}$	Al^{3+}	S	T	V(%)
0.80	0.40	0.17	0.04	0.66	0.10	1.4	2.1	68
C ($g\ kg^{-1}$)		N ($g\ kg^{-1}$)	C/N	MO ($g\ kg^{-1}$)	P assimilable ($mg\ kg^{-1}$)	m (%)		VST
1.91		0.19	10	3.31	2	7		8

For this type of soil, perennial crops promotes better results than annual ones. This will influence on the choice of agriculture crops and the intervals between them. The results also show that the soil does not need acidity correction and that there is no saturation by aluminum (m%), a toxic substance for plants. Also, there are no salinity problems as the levels are below the level considered critical. On the other hand, there is a low concentration of nutrients and organic matter, making it necessary to apply natural fertilizers and vegetable waste like sugarcane bagasse, coconut and animal manure, in order to replace the missing elements. Part of this need can be solved by the local treatment waste of animals and plants, generating organic fertilizers.

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Nexus Local Model

In relation to food production, it is important to consider a certain diversity in order to achieve a variety of food capable of meeting the local soil capacity coupled with the nutritional and energetic recommendations of the World Health Organization (WHO), as well as the purposes of the residents. According to the interviews, their eating habits are very similar and are based on rice, beans, chicken and bread. The residents would like more options of fresh vegetables and fruits, beef and fish, since the fishery has decreased significantly after the installation of shrimp farms in the area (O POVO, 2021), as well as products from fields, like corn and potatoes, which are no longer planted by the families.

Some production alternatives were listed and described in the sequence of this section that includes lots of vegetables, different kinds of meet and fruits, following the possibilities of local ecosystems.

Besides, emphasizing the existing interconnections between social and ecological demands regarding water supply, energy generation, and food production at a local scale, the network developed based on the Nexus approach seeks to cover the multilevel of alternative propositions and their restrictions on a multi-functional way. Figure 5 sought to characterize these interconnections.

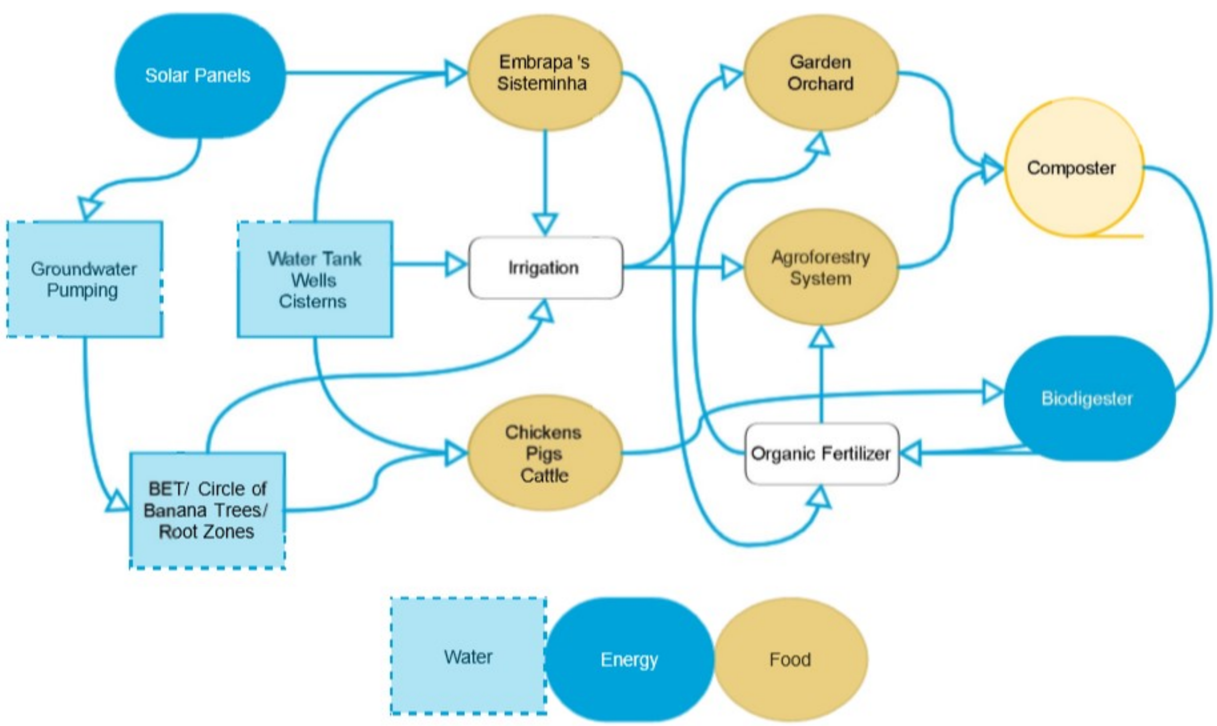

Figure 5. The interconnections between the constituent elements of the Nexus model of Brotando a Emancipação Ranch.

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Regarding the inputs and outputs of each element, it was found that all elements are dependent on water supply except solar panels (Table 2). This supply depends on reservoir systems for rainwater collection, considering that in the state of Ceará there is concentrated rainfall in the first half of the year. Thus, we suggested to treat and reuse wastewater so that there is no waste, as well as to carry out the treatment of plant and animal waste for the long-term sustainability of production. Each of the alternatives of the local Nexus model was described next to the text:

Table 2. Inputs and outputs of the constituent elements of the Nexus model at Brotando a Emancipação Ranch.

Inputs	Water	Water				Water	Water	Wastewater (gray and black)	
	Fry		Water	Water	Water				
	Ration	Organic Fertilizer				Pasture	Animal Waste	Evapotranspiration and Filtering Plants	Solar Energy
	Lime + Plaster		Vegetable Waste	Vegetable Waste	Vegetable and Animal Waste				
	Eletric and Solar Energy	Solar Energy				Solar Energy	Electric Energy	Solar Energy	
Elements	**SISTEMINHA**	**Garden / Orchard**	**COMPOSTER**	**CHICKEN**	**PIGGS**	**CATTLE**	**BIODIGESTER**	**BET / Circle of banana trees / Root Zones**	**SOLAR PANELS**
Outputs	Fish	Herbs	Organic fertilizer	Chicken / Broiler Chicken	Pig Meat	Beef	Biogas	Reuse Water	
	Organic Fertilizer	Vegetable		Eggs	Lard	Milk			Electric Energy
		Fruit	_Vegetable Waste Treatment*_	Animal Waste	Animal Waste	Animal Waste	_Animal Waste Treatment*_	_Wastewater (gray and black) Treament*_	
		Vegetable Waste							

The reproducibility of this local model considers other regions with similar natural characteristics, with the same type of soil, predominant in the semi-arid region of northeastern Brazil, little rainfall, elevated evapotranspiration, uninterrupted sunlight though the year, considerations over native vegetation and its natural cycles, in addition to eating habits and similar water and energy demands among the inhabitants.

Embrapa's Sisteminha

Embrapa's Sisteminha is the result of the research for feasible solutions to guarantee food sovereignty and meet the WHO nutritional recommendations with a diversification of food production in small rural properties in regions with little water availability, in which thousands of Brazilians find themselves, in a situation of extreme poverty.

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Its central element consists of a simplified technique of artisanal productivity for consumption. This technique uses an aerobic reactor which recirculates the water in a tank that can be made of plastic, cardboard, mud, masonry or cement board, allowing the creation of fish and the elimination of metabolic waste with high zoo-technical rigor. Its construction is simple and low cost and can be replicated by the general population, as can be seen in Guilherme (2005).

The advantages of this technique, in addition to the low investment cost and the possibility of implantation in small spaces (from 100m2), are the adaptability to the natural conditions of the place and the integration with food production, water treatment, and biogas production. Currently, Embrapa offers 15 modules that include the production of: fish; chicken eggs; broilers; earthworms; vegetables; organic compost; quail eggs; guinea pigs; aquaponic techniques; fly larvae; ruminants; pigs; biodigester; drinking water treatment system and; artisanal charcoal making. All modules benefit at some point from the nutrients generated in the fish tank, so this is the central element, and, from these modules, producers can adopt those that are following their interests, molding and developing them according to the evolution of production.

Permaculture

The structural design principles of a permanent production system must comply with some requirements, such as the location of each element of the system (agricultural area, animal husbandry, energy production) within zoning in order to facilitate that each one performs multiple functions, incorporating an efficient energy planning with a predominant use of biological resources. Also, local energy recycling, the formation of small-scale intensive systems, acceleration of natural succession, polyculture, species diversity, and use of natural patterns and borders should be considered as principles (Holmgren, 2013).

When positioning a specific element with another, we must consider the ecological principles for the optimization of interactions of mutual benefit, increasing the resistance of the system and decreasing the amount of energy spent on its maintenance. In this perspective, we proposed the Ranch's structural design, so that each element can enhance and supported by the others. In zoning, the components will be positioned according to efficient energy planning, and the zones will be influenced by factors such as the size and shape of the terrain, the accesses, the slope, soil characteristics, local ventilation patterns, and consideration of existing structures.

Permaculture proposes that the divisions of zones are following the intensity of activities in each area, as well as the interconnections between the elements. Mollison and Slay (1998) describe each zone and its elements, for example, in Zone 1 you should locate the household, little gardens and quiet animals like tanks of fish, consequently, in Zone 2 the elements must be the ones you put less energy on, like agriculture and biodigesters to supply the household and so on. The zoning proposed in this study is shown in Figure 6.

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Figure 6. Proposed zoning for Brotando a Emancipação Ranch.

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Notice that the proposed zoning does not consider the entire extension of the land since taking advantage of the existing structures is aimed to propose feasible interventions considering the ethical, financial, and available workforce aspects. Subsequently, it is possible to expand and adapt the Zones. The EPA will be considered as Zone 5, as it will remain untouched.

Considering the predominance of winds from the region in the eastern direction, with an average speed of 28 km h^{-1} (Meteoblue, 2019), classified as breezes, and intense solar incidence throughout the year, the objective was to plan the creation of animals parallel to the location of the house, so that odors did not bother the inhabitants and since there are no other houses nearby in that direction. For the chicken coop and pig breeding, it is interesting to have covered structures to protect the animals from the sun. The considerable area has been set aside for grazing and rearing ruminants.

The nutrients produced at Embrapa's Sisteminhas (Figure 6) located further north of the land, can be used for irrigation and fertilization of crops nearby. We locate the composter and earthworm close to the fish tanks, the house, and the animals' rearing, as this minimizes the energy expenditure on the destination of waste. Also, we located a house of seedlings and seeds close to the house and the compost pits since it will use the fertilizer. All these elements are located in Zone 1.

The biodigester (Figure 6), which will feed the house and other facilities, was also located in Zone 1, and it is worth mentioning that this process of anaerobic digestion through methanogenic bacteria does not produce strong odors, does not attract flies or contains parasite eggs. We located the Evapotranspiration Basin (ETB) next to the house, where the black waters are destined.

The water tank was located at the highest point of the land and next to the systems, in order to be able to formulate an efficient irrigation system that uses maximum potential gravitational energy to replace the water in the systems and to cover areas of vegetable gardens, orchards, fruit planting, and other agricultural areas. We also proposed that in the area where the land is the lowest point, a dike should be built to increase local water security.

Regarding the area destined to the Agroforestry System (SAF), this was historically used for livestock, according to information collected in the field. Therefore, it is necessary to previously apply methods of recovering degraded areas to decompress the soil and enrich it with nutrients. Some efficient techniques are reforestation based on the ecological succession with native plants, reproducing natural patterns, and planting matrices in the front line of the winds. In the area reserved for camping (Figure 6), dry toilets with showers and a circle of banana trees or a root zone for the treatment of gray waters can be built.

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Biogas and biofertilizers production

The advantages of producing biogas are several. From the negative carbon footprint, since CO2 is removed from the environment, contributing to the reduction of greenhouse gases, to the recycling of agricultural waste and obtaining of biofertilizers. The resource can be stored and used as needed, different from energies such as solar and wind, which, in absence of batteries, depend on the incidence of sunlight and winds for its supply.

The system provides the production of biogas through the biodigestion of manure from birds, pigs, and ruminants. Embrapa (2005) provides booklets aimed at the dimensioning of pig, cattle, and poultry manure biodigesters considering storage capacities of different volumes, according to the reality of producers in each state.

In addition to the biofertilizers obtained through the biogas production process, there are biofertilizers coming from composting plants and, to a lesser extent, from the earthworms. Composting aims to stabilize and decontaminate, chemically and biologically, materials and residues from agricultural production to be applied in agriculture.

The composting duration varies according to the characteristics of the plant residues applied, the biomass temperature, and the use of fertilizer produced, usually between 60 and 120 days. During the process, the biomass must be moistened. There is no need to add inoculants or any other chemical elements.

Solar Energy

To complement the energy supply in The Mangabeira Community in an economical, technically feasible, and ecologically responsible way, we proposed to use alternative energies, more specifically solar energy. The provision of large portions of spaces and free surfaces combined with the intense solar incidence in the Ecuadorian region makes this type of energy production quite efficient throughout the year. We suggested the distributed generation type system (connected to the electrical network) to send any excesses to the network or compensate in times of scarcity.

Another possibility is to apply part of this energy to pump groundwater to supply the community, already carried out through the Sisar Project, which presents advantages such as easy implementation, operation, and maintenance since it already has the necessary infrastructure. Besides, groundwater is generally a better source of water, because it is protected from polluting agents that affect water quality.

From this perspective, photovoltaic pumping systems monitor water demand with an increase in the equipment power. Additionally, there is the advantage of the union between the time

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profile of this resource and the demand, as periods of high insulation correspond to those of higher water consumption, both daily and seasonally (Boitrago *et al.*, 2016).

It is possible to adopt plates with a production capacity of 35 kWh, power of 265 Wp and measuring 99cm x 165cm, as they are the most common on the market in Ceará (Fotaic, 2020), 206 plates would be necessary, which can be coupled in panels, for the supply of 7.2 MWh. The final power of the set will be of 54.6 kWp and occupied space of 370.80m2 (considering the space of 1.80m2 per plate added by screws and cables).

Conclusions

This study sought to contribute to the development and applicability of the Nexus approach at a local level, considering its complexity, depth, and interdisciplinary dimension. We concluded that for the effective implementation of the Nexus as an intersectoral methodology and practice in facing contemporary challenges, innovation must be counted, not only technical but also social and philosophical, as collaboration, multiple approaches, and definition of objectives compatible with the capacity to renew the resources applied.

Concerning the observed elements and interconnections, we encountered difficulties in terms of data analysis and systematization. We often applied matrices to map the connections between subsystems and efficient methods when considering two or three relationships between different elements. When these connections become more complex, it is no longer possible to use a linear systematization method, as these relations are often circular and dynamic, occurring simultaneously or successively, requiring the transfer of the mapping performed to methods of complex systems analysis.

Thus, concerning governance related to water management, a Nexus approach that includes ecosystem aspects, such as the one adopted, ends up inevitably considering the possible local impacts on broader systems. The hydrographic basin of the region, for example, where the processes are inserted, like input volumes and nutrient loads from wastewater, the dynamics of animal and plant communities, biogeochemical cycles, including the assessment of land use and their interactions with energy production infrastructures within the dynamics of climate change.

Bearing in mind that not only economic crises, but also ecological and public health crises are part of the horizon of the modern globalized economic system, the search for new paradigms gains not only strategic but also moral relevance, even in terms of survival. The concept of integrated, holistic management, planning, production, and access to essential goods and services is indispensable for responsible, sustainable social reproduction and consistent with the limits imposed by the finite availability of natural resources.

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The approach developed here has a qualitative character, based on proposals that consider existing structures and sustainable resource management practices that can be adapted to local financial, cultural and physical realities. The manuscript aims to contribute to the dissemination and construction of a local management model that utilizes the Nexus approach, which is still very incipient and difficult to standardize. As more institutions promote specific studies and procedures based on Nexus, more promotion of funding and creation of a growing body of professionals and research, aiming the consolidation of these methodologies and tools.

References

Albrecht, T. R., Crootof, A., Scott, C. A. (2018) The Water-Energy-Food Nexus: A systematic review of methods for nexus assessment. *Environmental Research Letters*, **13**(043002). https://doi.org/10.1088/1748-9326/aaa9c6.

Baldin, N., Munhoz, E. (2011) Snowball (Bola de Neve): uma técnica metodológica para pesquisa em educação 488 ambiental comunitária. *X Congresso Nacional de Educação (EDUCERE) - I Seminário Internacional de* 489 *Representações Sociais, Subjetividade e Educação (SIRSSE)*, **1**, 329–341.

Bleischwitz, R., Spataru, C., Vandeveer, S., Obersteiner, M., Van Der Voet, E., Johnson, C., Andrews-Speed, P., Boersma, T, Hoff, H., Van Vuuren, D. (2018) Resource nexus perspectives towards the United Nations Sustainable Development Goals. *Nature Sustenability*, **1**, 737-743. http://dx.doi.org/10.1038/s41893-018-0173-27

Brouwer, F., Avgerinopoulos, G., Fazekas, D., Laspidou, C., Mercure, J. F, Pollit, H., Ramos, E. P., Howells, M. (2018) Energy modelling and the Nexus concept. *Energy Strategy Reviews*, **19**, 1-6. https://doi.org/10.1016/j.esr.2017.10.005.

Boitrago, S. A., Santos, S. S., Ramos, M. A. C., Ribeiro, A. H. G. (2016) Captação De água Por Sistema voltaico Para Consumo Humano Na Localidade Rural Ilha Caiapós, São Romão - Minas Gerais. In *REEC - Revista Eletrônica de Engenharia Civil*, **12**, 2179-0612.

Cai, X., Wallington, K., Shafiee-Jood, M., Marston, L. (2018) Understanding and managing the food-energy-water nexus - opportunities for water resources research. *Advances in Water Resources*, **111**, 259-273. https://doi.org/10.1016/j.advwatres.2017.11.014.

COGERH, Companhia de Gestão dos Recursos Hídricos (2019) Atlas Eletrônico dos Recursos Hídricos do Estado do Ceará. Disponível em: http://atlas.srh.ce.gov.br/infra-estrutura/acudes/index.php?status=1 Accessed on 12 October 2019

El Bilali, H. (2018) Transition heuristic frameworks in research on agro-food sustainability transitions. Environment, development and sustainability, **22**, 1693-1728. https://doi.org/10.1007/s10668-018-0290-0

Embrapa, Empresa Brasileira de Pesquisa Agropecuária (2005) Projeto de Biodigestor e Estimativa de Produção de Biogás em Sistema de Produção. Empresa Brasileira de Pesquisa Agropecuária. Comunicado Técnico, Concórdia, SC. Accessed on 02 April 2020. Disponível em: https://www.embrapa.br/gadode-leite/busca-de-publicacoes/-/publicacao/1025416/dejetos-bovinos-para-producao-de-biogas-ebiofertilizante-por-biodigestao-anaerobica

ENEL, Ente Nazionale per l'Energia Elettrica (2019) Taxas, Tarifas e Impostos. Accessed on 25 March 2020. Disponível em https://www.enel.com.br/pt-ceara/Tarifas_Enel.html

EPE, Empresa de Pesquisa Energética (2019) Anuário Estatístico de Energia Elétrica 2019: Ano Base 2018. Rio de Janeiro, RJ, 2019.Empresa de Pesquisa Energética-EPE. Accessed on 25 March 2020. Disponível em: http://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/anuario-estatistico-de-energia-eletrica.

Revista AIDIS de Ingeniería y Ciencias Ambientales:
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http://dx.doi.org/10.22201/iingen.0718378xe.2022.15.1.78075
Vol. 15, No.1, 364-383
6 de abril de 2022

Ferraço, A. A. G., Moraes, G. G. B. L. (2018) O direito e a aplicação do nexo água-alimento-energia: antigos pressupostos e novas abordagens na gestão dos recursos. *Revista do Programa de Pós Graduação em Direito* – UFC, Fortaleza, **38**(2), 564-583.

Fotaic. (2020) Manual da Energia Solar: Tudo que você precisa saber antes de comprar seu kit solar. Fortaleza, Ceará. Accessed on 10 April 2020. Disponível em: https://www.fotaic.com.br/blog

Guilherme, L. C. (2005) Estudos reprodutivos, citogenéticos na população de *Rhamdia quelen* (pisces, Rhamdiidae) do Rio Uberabinha no município de Uberlândia - MG e desenvolvimento de sistema artesanal de recirculação d'àgua para criação de peixes. Tese (doutorado) – Universidade Federal de Uberlândia, Programa de Pós-Graduação em Genética e Bioquímica, Uberlândia, MG.

Hoff, H. (2011) Understanding the Nexus. *Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus.* Stockholm Environment Institute, Stockholm.

Holmgren, D. (2013) *Permacultura: princípios e caminhos além da sustentabilidade.* Tradução Luzia Araújo. Porto Alegre: Via Sapiens. 416 pp.

Instituto Nacional de Pesquisas Espaciais (INPE) Topodata: banco de dados geomorfométricos do Brasil. Variáveis geomorfométricas locais. São José dos Campos. Accessed on 20 March. Disponível em : http://www.dsr.inpe.br/topodata/2020

Kolbert, E. (2015) *A sexta extinção: uma história não natural*. 1ª ed. Rio de Janeiro: Intrínseca.

Leão, M. D. M. (2018) Diversidade da entomofauna edáfica no "Sítio Brotando a Emancipação/Cascavel-CE", em diferentes coberturas vegetais e períodos sazonais. Trabalho de Conclusão de Curso (graduação), Universidade Federal do Ceará, Centro de Ciências Agrárias, Curso de Agronomia. Fortaleza, CE.

Mapbiomas. Coleções 2014, 2015, 2016, 2017 e 2018. Transição do Uso e Ocupação do Solo. Accessed on 17 September 2019.Available online: http://plataforma.mapbiomas.org/map#transitions

Mollison, B., Slay, R. M. (1998) *Introdução à Permacultura*. Brasília: MA/SDR/PNFC.

Mercure, J. F., Paim, M. A., Bocquilon, P., Lindner, S., Salas, P., Martinelli, P., Berchin, I. I., De Andrade Guerra, J. B. S. O., Derani, C., De Albuquerque Junior, C. L., Ribeiro, J. M. P., Knobloch, F., Pollit, H., Edwards, N. R., Holden, P. B., Foley, A., Schaphoff, S., Faraco, R. A., Vinuales, J. E. (2019) System complexity and policy integration challenges: The Brazilian Energy - Water-Food Nexus. *Renewable and Sustainable Energy Reviews*, **105**, 230-243. https://doi.org/10.1016 /j.rser.2019.01.045

Olawuyi, D. (2020) Sustainable development and the water-energy-food nexus: Legal challenges and merging solutions. *Environmental Science and Policy*, **103**, 1-9.

O POVO (2021) Empresas são multadas e embargadas por viveiros ilegais de camarão entre Beberibe e Cascavel. O POVO. Fortaleza, 24 de abril de 2021. Available in: https://mais.opovo.com.br/jornal/cidades/2021/04/24/empresas-sao-multadas-e-embargadas-por-viveiros-ilegais-de-camarao-entre-beberibe-e-cascavel.html

SNIS, Sistema Nacional de Informações sobre Saneamento (2019) Diagnóstico dos Serviços de água e Esgoto 2018. Brasília, 2019. 544 Sistema Nacional de Informações sobre Saneamento – SNIS. Accessed on 20 March 2020. Disponível em: http://www.snis.gov.br/diagnostico-anual-agua-e-esgotos/diagnostico-dos-servicos-de-agua-e-esgotos-2018

Sisar. Instituto Sisar. (2020) Projeto São José – Sistema Integrado de Saneamento Rural. Accessed on 15 March 2020. Disponível em: http://www.sisar.org.br

Staupe-Delgado, R. (2020) The water-food-energyenvironmental nexus: movind the debate forward. Environment, Development and Sustainability, **22**, 6131-6147. https://doi.org/10.1007/s10668-019-00467-5

Terrapon-Pfaff, J., Ortiz, W., Dienst, C., Gröne, M.C. (2018) Energising the WEF nexus to enhance sustainable development at local level. *Journal of Environmental Management*. **223**(June), 409-416.

Vinuto, J. (2014) A amostragem em bola de neve na pesquisa qualitativa: um debate em aberto. *Temáticas, Campinas*, **22**(44), 203-220.

Zhang, C., Chen, X., Li, Y., Ding, W., Fu, G. (2018) Water-energy-food nexus: Concepts, questions and methodologies. *Journal of Cleaner Production*, **195**, 625–639.