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Electricity and Family Farmers in Brazil's Semi-Arid Region: Perceptions and Vulnerabilities

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Abstract

This paper seeks to raise questions and analyze aspects of the remaining energy poverty as it relates to the vulnerability of family farmers in the semi-arid region of Brazil, such as; what are the remaining energy needs of family farmers in the region? What are their perceptions concerning energy access and affordability? What are possible options for sustainable energy technology deployment in the region?

Four case studies carried out in 2011 and 2012 will be presented. The focus on family farming is important because this sector is highly sensitive to climate stimuli, has low capacity to deal with and prevent impacts of climate variability and is an important source of food production in Brazil.

The results show that irrigation is used only in a small minority of the rural properties while #80 percent of the sample relies solely on rain-fed agriculture, leaving them highly vulnerable to variable precipitation. Energy access is cited as a difficulty in their production activities in varying extents: 9 percent in Piauí and 4-5 percent in the other three cases. Within the sub-population that used electricity for irrigation, there was a wide variety of perceptions on the affordability of the energy. For example, in Bahia one-third cited energy to be expensive, while in Rio Grande do Norte about 80 percent considered that the cost is low or moderate.

Key Words: *Energy poverty, Electricity access, Brazilian semi-arid, family farmers/smallholders*

1. Introduction

In the last decades, rural areas in the Northeast of Brazil have experienced great change in living conditions; in a large extent due to specific policies aiming at improve quality of life in the Region. This has been reflected in the increase of Human Development Index, HDI shown in Figure 1. At the community level, improvements in access to education and health services are noted, while at the household level, policies focused on housing and access to credit. The national Light for All (*Luz para Todos*) programme resulted in providing electricity to over 15 million Brazilians since 2003 (MME, 2014). Specifically for the semi-arid region, a vast program of storage of drinking water distributed more than half a million cisterns to farms (Viana, 2013).

The Northeast of Brazil, one of the five, large Brazilian regions is comprised of nine states; Alagoas, Bahia, Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe (see Figure 2). According to IBGE, the Brazilian Statistical and Geographical Agency, it occupies 18 percent of the national territory and has a population of approximately 53 million inhabitants. The Northeast also concentrates one of the most fragile and exclusively Brazilian biomes; the Caatinga (see Figure 3).

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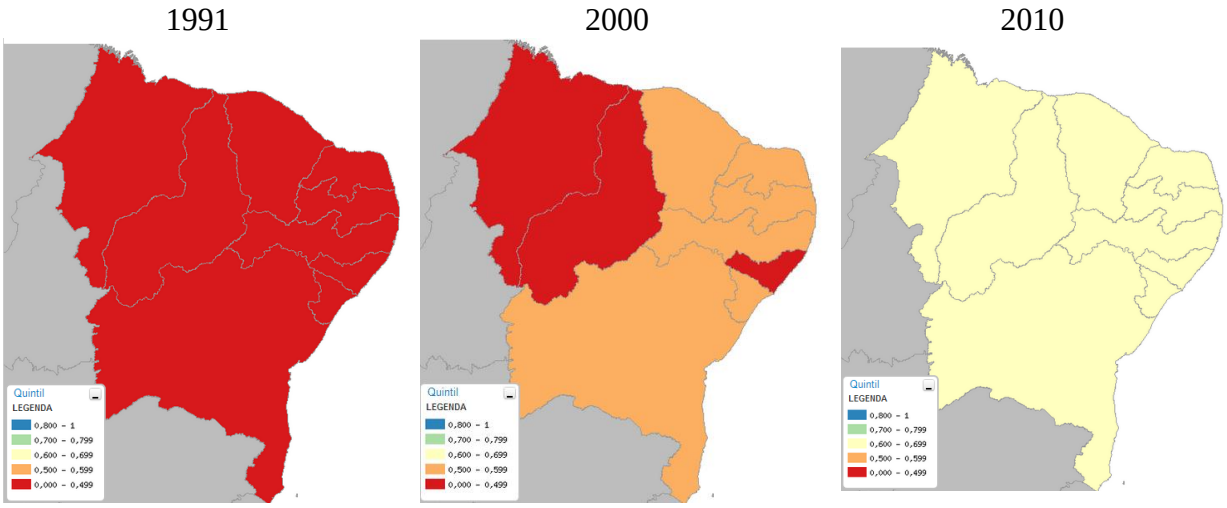


Figure 1: Evolution of Human Development Index for the Brazilian States of the Northeast Region, Source: (UNDP et al., 2013)

The origin of the world Caatinga comes from the indigenous Tupi language meaning "white forest". It occupies approximately 10 percent of the Brazilian territory (Litre et al., 2014).

The semi-arid region of Brazil is defined politically by a regulation issued by the Ministry for National Integration (*Portaria no. 89* of March 16, 2005), which takes into account precipitation, evaporation rates and risk of drought. It is a region that has historically been marked by climate variability, irregular rains and severe droughts (Viana, 2013). What aggravates the situation further is that it projected to be one of the Brazilian regions most sensitive to climate change and it is also home to the majority of family farmers in the Northeast (Lindoso et al., 2013).

In a context of increased climate variability, social policies and emergency actions have reduced the vulnerability of family farmers[1] by attenuating the impacts of extreme drought on humans systems. However, in the semi-arid region, extreme events still severely damages the producing activities: mortality of livestock remains high, and crops are often lost (Lindoso et al., 2013).

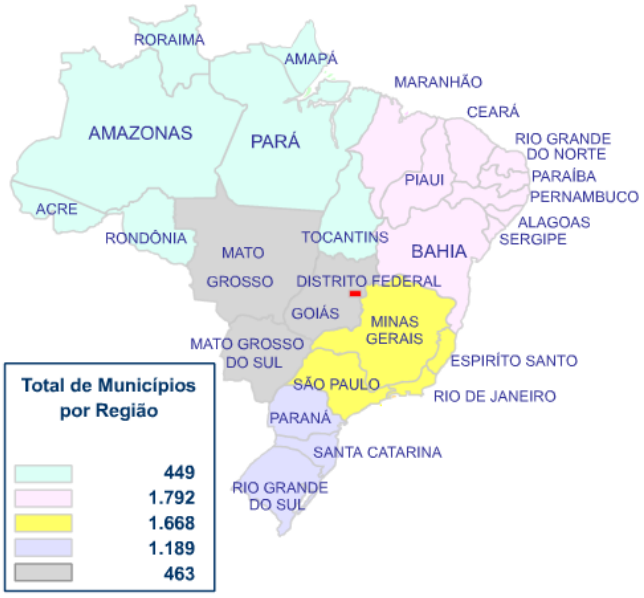


Figure 2: Brazil, Large Regions and States (IBGE, nd)

[1] Family farming is defined in Brazil by Federal Law No. 11.326 of June 2006. In its definition of Family Farming, the law limits the size of the property to 4 fiscal modules (that can vary by municipality), which must be managed and operated by the family and employ predominantly the family`s own workforce.



Figure 3: Brazil, Biomes (IBGE, 2004)

Indeed, policies related to reducing the vulnerability of agriculture remain inadequate and outdated: in the semi-arid, technical assistance is ineffective. For this reason, agricultural practices have by-in-large remained unchanged, and the effects of climate events on agriculture and cattle raising remains very similar to what was observed during the droughts of the twentieth century.

This paper will take a more in-depth look into the data collected in the four case studies in the semi-arid region of Brazil in order to elaborate on the linkages between the productive uses of energy within the energy-water-climate nexus. By productive uses of energy, we will use the concept laid out by the Global Environmental Facility, GEF and the Food and Agricultural Organization of the United Nations, FAO; "a productive use of energy is one that involves the application of energy derived mainly from renewable resources to create goods and/or services either directly or indirectly for the production of income or value" (Cabraal et al., 2005). This is a very broad concept, which could include fuel for transportation of good to market, for example. Our focus for this study will be limited to electricity, its use and cost in family farming establishments within the four case studies in the semi-arid region of the Northeast of Brazil (which will be presented in the Methodology section).

The linkages between energy, water, climate and poverty, often referred to in literature as Nexus studies (Casillas and Kammen, 2010) is a pertinent object of research, especially considering that food production consumes approximately about 30 percent of total global energy and is responsible for 20 percent of global Greenhouse Gas, GHG emissions (FAO, 2011). The landscape approach of linking resource management and poverty reduction in order to provide opportunities for the needs of rural communities has often lacked an energy component (ibid, p. 34). In their report on energy-smart agriculture (2011), FAO highlights the need to combine renewable technologies to generate energy along with efficient irrigation methods to increase crop yields as one example of this approach. The Organization prepared a recent report on the Nexus, stating that it must be framed within the broader sustainability debate (FAO, 2014).

Within the Nexus framework, one of the key questions that the study will try to address is; what are the remaining productive energy needs (electricity) of family farmers in the semi-arid region of Brazil? In a recent paper prepared by the International Institute for Environment and Development, IIED productive energy needs are defined as "energy that directly increases incomes or adds value to goods and services" (Best, 2014, p. 4). This goes beyond the traditional approaches of rural electrification as it attempts to englobe the role that energy can play in having both mitigation effects for climate change as well increase the adaptive capacity of the farmers.

From the comparison of the four cases, the goal of the paper is to identify aspects of the remaining energy poverty as it relates to the vulnerability of family farmers in the semi-arid region of the Northeast of Brazil. More amply, the study will reflect on the larger problematic related to energy affordability; appropriate, sustainable energy technology deployment in the region for agri-cultural production and irrigation and the public policies that support such activities.

2. Methodology

The data presented in this paper was collected as part of a larger research agenda carried out by the Climate Change and Regional Development sub-network of the Brazilian Research Network on Global Climate Change; *RedeCLIMA*.

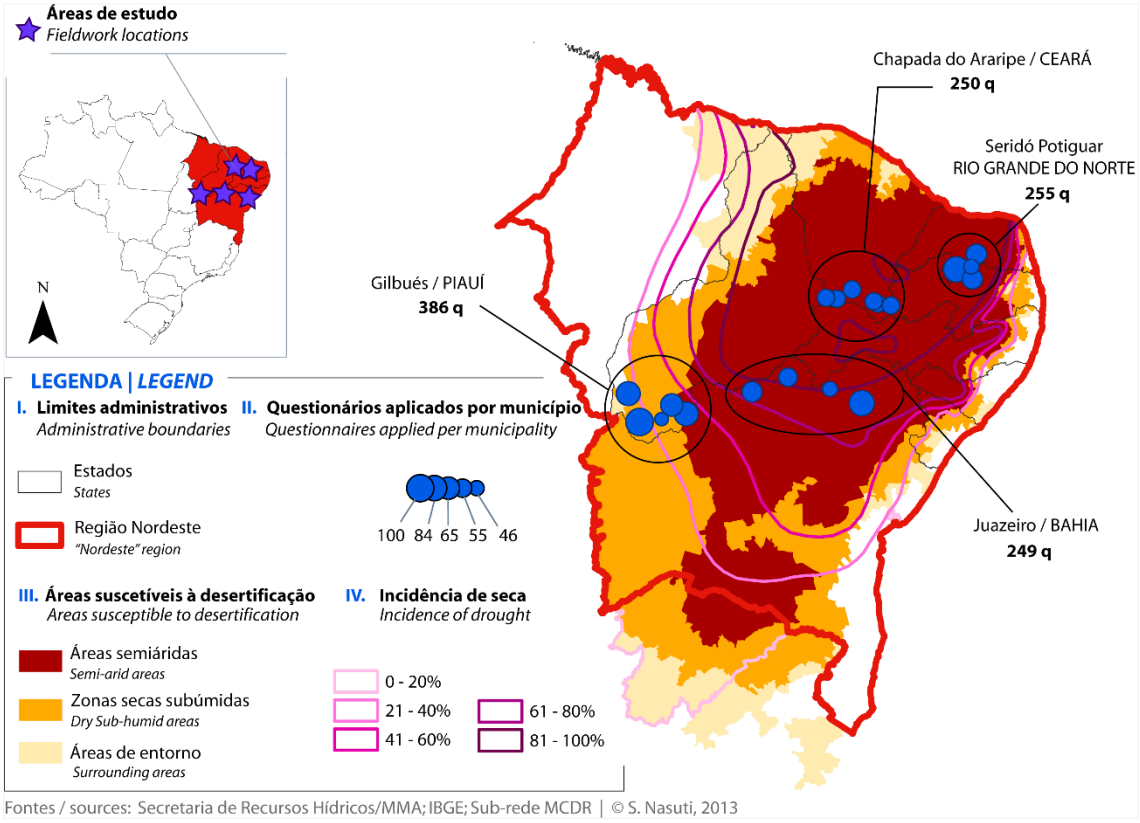


Figure 4: Location of the case studies

The research focus is on family farming in four of Brazil biomes: Cerrado, Amazon, Pantanal and Caatinga. To date, research has been conducted in 26 municipalities (10 case studies), utilizing the same research protocol, which included a questionnaire interview with family farmers to allow for comparison.

The questionnaire is divided in 7 parts: (1) respondent general information, (2) productive activity, (3) economic aspects, (4) social aspects, (5) political and institutional aspects, (6) environmental aspects, and (7) climatic considerations. The questionnaire used in these surveys is the result of a collective and interdisciplinary work, refined at each stage of the research, and adapted for each context and regional particularities, while maintaining its essential traits that allowed the comparison here proposed. For data processing and statistical analysis, software SPHINX IQ was used.

For the purpose of this paper, we restricted our sample to four case studies located in the Brazilian semi-arid region, in the states of Bahia, Rio Grande do Norte, Piauí and Ceará. These have been selected through a combination of socioeconomic and climatic characteristics, aiming at best representing the micro-regional vulnerabilities. Over one thousand interviews by questionnaires were held with family farmers in 18 different municipalities[2] (see Figure 4).

It is important to stress that the research and its tools were designed to analyze family farmers' vulnerability, adaptation strategies and climate perceptions. However, this paper will focus on the questions dealing with productive needs of energy (electricity), as previously explained in the introduction. To do so, we specifically analyse the data (in section 4) related to the family farmers' perception of electricity access, uses and costs within the context of their agricultural activities.

In the state of Bahia, the fieldwork was carried out in June and July of 2011 in four municipalities in the region of the Sertão do Rio São Franciso. In their

[2] Total interviews were 1,140.

study of the region, (Lindoso et al., 2013) identified that geographical location, i.e. the distance to the river, along with environmental and technological determinants (irrigation) were key factor in the differing results in the adaptation capacity amongst family farmers.

The case study in the Seridó region of Rio Grande do Norte took place in October and November 2011. Nasuti et. al (2013) characterize the region as a highly fragile ecosystem, one where over 2 thousand square kilometers are already being affected by desertification. This has mainly been caused by anthropic actions, such as deforestation, animal grazing and more recently clay and wood extraction to produce ceramics.

In the state of Piauí, the field work was carried out in May and June of 2012 in the region known as the Desertification Nucleus of Gilbués **(***Núcleo de Desertificação de Gilbués, NGD*), which is one of desertification hot-spots in the Northeast. This region, located in an area of transition between the Caatinga and Cerrado biomes in the South of the state of Piauí has undergone an intense process of land degradation, which along with lack of access to water has created important social and economic implications for Family farmers (Pedroso, 2013).

In the State of Ceará, the fieldwork was carried out in the region of the Chapada do Araripe/Cariri Region in November 2012. It is located in the south of the state, with two distinct characteristics; in the hilly municipalities of the Chapada do Araripe (plateau area), the climate is more humid. In the areas in the lower portion of the sedimentary basin, the production of corn, beans and cattle activities are predominant and it is also home to one of the most important archeological sites for fossils in the country (Lindoso, 2013)**.**

Table 1

General characterization of the rural establishments

Case study	Gilbués / PIAUÍ	Seridó / RIO GRANDE DO NORTE	Juazeiro / BAHIA	Chapada do Araripe / CEARÁ
Percent depending on only rainfed agriculture	67,6%	45%	61,2%	96,8%
Uses any kind of irrigation system	1.3%	16.6%	30.6%	7.2%
Average size of plantation (hectares)	3,3	3,2	*No data*	2,4
Main crops	cassava, black beans, corn			
Livestock (Animal husbandry activity)				
Cattle ranching (%)	59%	59%	26%	26%
Average size of cattle herds (number animals)	11	9	11	
Diversification of family income				
Percent of households where at least one member …				
Receives social allowances (*Bolsa Família*)	60,3	45,6	53,2	66,6
Receives a pension	34	43,6	41,6	38,2
Works outside #their farm in rural area	12,1	18,7	12,8	39,8
Access to electricity				
Electricity access, domestic use	62% (grid); 2% (in situ)[3]	*No data*	*No data*	98,8%

Source**:** Fieldwork 2011, 2012, 2013, Climate Change and Regional Development sub-network

[3] In the case of Gilbués-PI; 112 respondents (29.5 percent) indicated that they had no access to energy on their property

Table 2

Main production difficulties and losses linked to climate events

	Gilbués / PIAUÍ	Seridó / RIO GRANDE DO NORTE	Juazeiro / BAHIA	Chapada Araripe / CEARÁ
Access to water	46.1%	46.1%	54.0%	28.9%
Weather / Climate	51.8%	51.8%	33.6%	30.1%
Access to credit	21.8%	34.9%	15.2%	14.5%
Lack of technical assistance	24.7%	24.7%	6.4%	4.8%
Access to energy	9,2%	##2.8%	##	
		Impact of climate events		
% that already suffered some kind of loss due to climate events		68.5%	79.2%	*
		Main losses suffered		
Animal losses	37.6%	19.1%	54.4%	*
Crop losses	77.1%	56.8%	47.2%	*
Reduction in productivity		16.6%	13.6%	*
		Causes of the losses		
Drought / lack of rain	89.9%	63.6%	62.4%	*
Heat	2.2%	6.1%	23.2%	*
Excess of rainfalls / storms / floods	1.4%	37.6%	16.4%	*
Pests/ Diseases	1.4%	18.8%	15.2%	*

Source: Fieldwork 2011, 2012, 2013, Climate Change and Regional Development sub-network; **not yet available*

3. Case Studies: Context and Characterization

The demographic growth of Brazil is mainly linked to the development of small and medium cities: urbanization rates now reaches about 84 percent (IBGE, 2010). However, in demographic terms, family farming still represents a substantial amount of the population, as it involves more than 12 million people and counts for about 4 million family farms in the whole country, of which 2.1 million are in the Northeast region.

According to the last Agricultural Census (2006) family farms contributed to 10 percent of Brazil's Gross Domestic Product (GDP), as it produces most of basic items of Brazilian food consumption, such as cassava (87 percent), corn, beans (70 percent) and milk (58 percent) (IBGE, 2006). Nevertheless, this group is one of the most vulnerable to climate variability and change. Indeed, they have the smallest capacity to deal with and prevent its impacts on production and food security.

The drought of 2012, which has been described by the producers as one of the most intense of the last forty years, had a dramatic impact across the Northeast region: some regions spent more than 16 months with no significant rainfall. The impacts were especially catastrophic for cattle breeding –as forage is almost inexistent among family farmers–, and for crops. Indeed, rainfed agriculture is predominant, and characterizes almost 80 percent of the producers interviewed (see Table 1). In our sample, only a small fraction of our respondents cited having access to any irrigation system (see Table 2). This means that the producers rely only on rainfall for crops and breeding, and are highly vulnerable to climatic conditions, both in terms of the amount of rain as well as the period/timing of rains.

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Brazilian family farmers are not a homogeneous group, as can be seen in the Table 2. Especially when considering irrigation of crops. Almost one third of the sample in Bahia irrigate, in stark contrast to 1.3 percent of establishments that irrigate in the case in Piauí. The wide discrepancy in the participation of irrigation amongst the case studies further highlights a unambiguous reality in the Brazilian semi-arid, that being the co-existence of various "semi-arids", as well as a lack of context-appropriate policies to support family agriculture.

Lindoso et al. outline the history of the particular region of Bahia considered in this study, which lies on banks of the most important River in the Northeast; São Francisco. Various government efforts to increase the economic participation of agriculture in the GDP of the Northeast and modernize agriculture began in the 1970's, which resulted in the creation of very distinct "agroindustry" centre (or enclave) in the São Francisco river valley. Currently it is a mosaic of irrigated crops produced mainly for exports alongside subsistence, rainfed farming. The case study is also in close proximity to the Sobradinho hydroelectric dam, which has created a history of land conflict related to displaced farmers (Lindoso et al., 2013, pp. 305–6)

On average over the four cases, 70 percent of the producers interviewed declared to have already suffered some kind of loss due to climate events, mainly droughts, excess of rainfalls, heat or displacement of the rainy season (see Table 2). Climate factors and difficulties to access water have been classified by the producers as the most significant challenges for producing, leading them in many cases to abandon the most fragile crops (rice in the Piauí, cassava in the Rio Grande do Norte, corn). One of the most common adaptation measure reported is to adapt the sowing period to the beginning of rainfalls.

4. Productive Uses of Energy

4.1 Access to Electricity

Access to Electricity in Brazil has improved significantly since 2003 when the Federal programme Light for All (*Luz para Todos*) was introduced. To date, the program has resulted in providing electricity to over 15 million Brazilians. It was extended until 2014 when the 2010 Demographic Census demonstrated that 716,000 households remained without grid-electricity access (MME, 2014).

According to the more recent PNAD (National Household Sample Study, 2013) Study shown in Table 3, there were still about 1 million Brazilians without access to electricity in 2012, almost half of which are located in the Northeast of the country.

With respect to the specific rural reality, the last agricultural census data is from 2006, however it shows that there existed a large inequality with respect to electricity access. The state of Bahia and Piauí, for example are 30 percent below the national average, while the state of Ceará is 12 percent higher, as shown in Figure 5.

Table 3

Population (thousands) that lack electricity access

	Year										
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2011	2012
Brazil	7,652	6,465	5,920	6,816	6,089	5,250	3,958	2,940	2,406	1,438	1,018
North	355	329	293	1,794	1.479	1,545	1,128	820	788	656	485
Northeast	5,534	4,776	4,426	3,918	3,689	2.971	2,326	1,689	1,352	663	458
Southeast	752	608	517	497	446	359	200	180	157	51	42
South	580	367	331	288	249	190	133	144	73	34	16
Centre-west	432	385	352	320	225	185	171	107	37	34	18

Source: (IBGE, 2013)

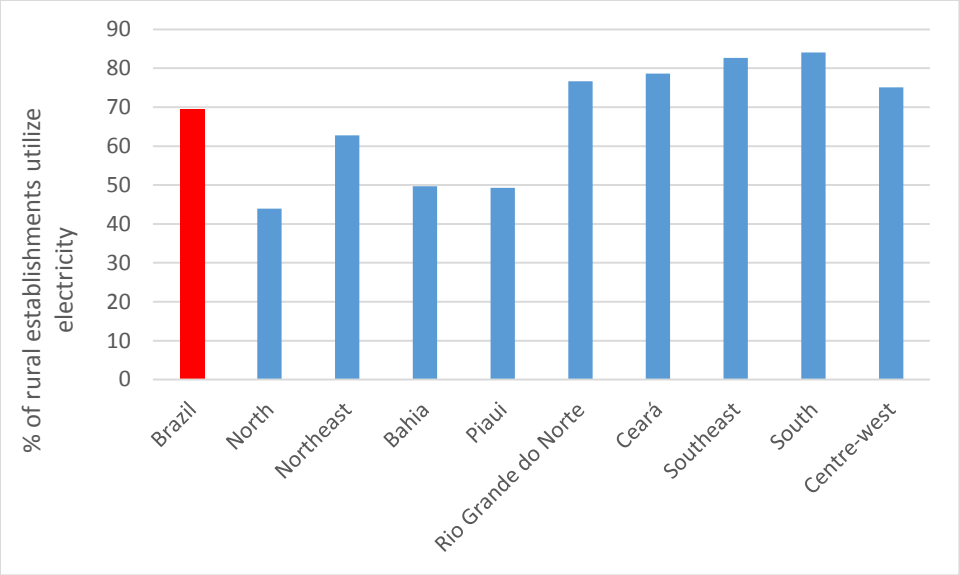


Figure 5: Access to Electricity in Rural Establishments, 2006 (IBGE, 2006)

In terms of access to electricity in the case studies included in our analysis, only the cases in Ceará and Piauí were explicitly asked about their access to electricity. There is a stark contrast between the two; in Gilbués 29.5 percent of respondents indicated having no electricity access on their property, as opposed to 1.2 percent in the Chapada do Araripe/Ceará. In Gulbués, 2.9 percent indicated having solar energy and 5.4 percent responses indicated some sort of combustion for electricity generation (oil/diesel generators). This was the only case study in which access to electricity was identified as a difficulty for production in any statistically significant manner (9 percent, see Table 2).

Within the Gilbués/PI case study, there is also a large variance of electricity access; two of the municipalities indicated a lack of electricity access in excess of 40 percent (Avelino Lopes and Gilbués), while in the other municipalities of Corrente, Curimatá and Parnaguá, the responses were 10, 14 and 1 percent respectively. This variance in electricity infrastructure was also captured Pedroso's study in the Desertification Nucleus of Gilbués. What is interesting in her analysis is the cross-inference with farmer's risk perception (i.e. recognition of the Climate Change phenomenon). She concluded that in communities with higher rates of access to energy, the perception of risk was highest, that being; energy access increased the adaptive capacity of the family farmers (Pedroso, 2013, p. 95).

It is interesting to note the existence of solar energy in almost 3 percent of the sample in Gilbués. In Bahia, 9 percent of respondents also indicated having solar energy specifically for powering irrigation, while in Seridó it was 2 percent. This meagre participation of solar energy is however, an interesting point that should be studied in further detail to understand the origins of such technology and how barriers were overcome for its successful deployment. Rural electrification in Brazil did not begin with the Light for All program. In 1994, the PRODEEM program **(**Energy Development Program in States and Municipalities, *Programa de Desenvolvimento Energético dos Estados e Municípios*), which is sometimes erroneously referred to the Rural Electrification Program using photovoltaics, PV because that was the dominant generation source. The program had a specific phase for PV energy for providing electricity for irrigation, in which 800 water-pumping systems were installed (Ruiz et al., 2007, p. 2990). In 2003, the PRODEEM program was incorporated into the newly inaugurated *Luz Para Todos* Program.

4.2 Energy for Irrigation

In terms of energy for irrigation, all but the case of Gilbués/PI were asked to identify the type of energy used for this process. In the three cases shown in Figure 6, it is clear that electricity is the dominant

energy source, while gravity flow and combustion generation are also employed to a lesser extent.

4.3 Perceptions of the Cost of Energy

In the cases of Gilbués/PI and the Chapada do Araripe/CE, the survey asked the family farmers to identify the participation of the cost of irrigation in the total cost of their production (*Se usa irrigação, qual o custo da irrigação no custo total da produção irrigada?*). In Gilbués, 60 percent of the respondents indicated that the participation was high, while the remaining 40 percent indicated that it was reasonable. In Chapada do Araripe, 28 percent indicated that the cost was "very high", 44 percent indicated "high", 17 percent reasonable.

In the same two cases, the survey asked the farmers to identify the sources for the costs of irrigation *(Se usa irrigação, o que é que torna a irrigação cara?*). As show in the Figure 7, 80 percent of responses in Gilbués/PI indicated that energy costs were the reason that irrigation expensive, while in Chapada do Araripe/CE, 44 percent indicated energy as the main cost item.

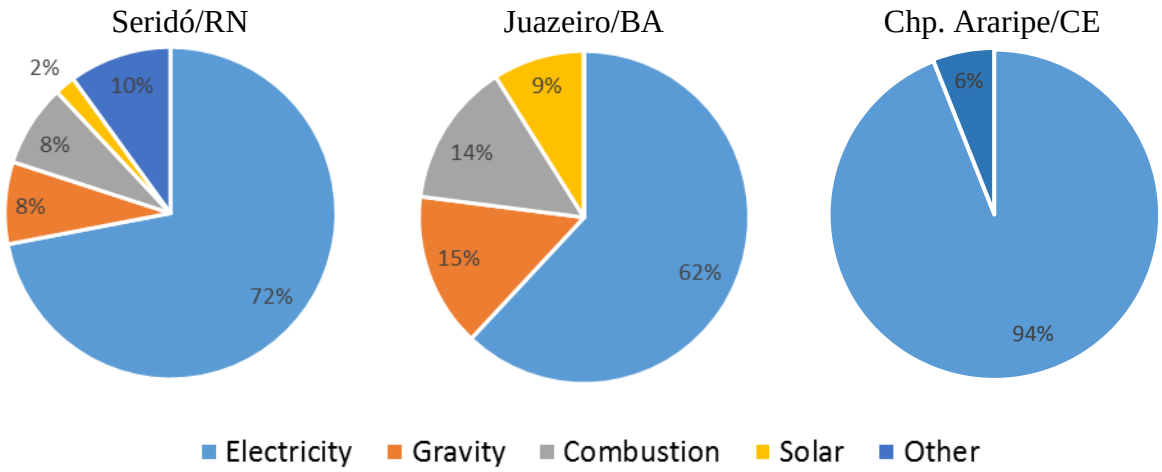


Figure 6: Energy Source for Irrigation

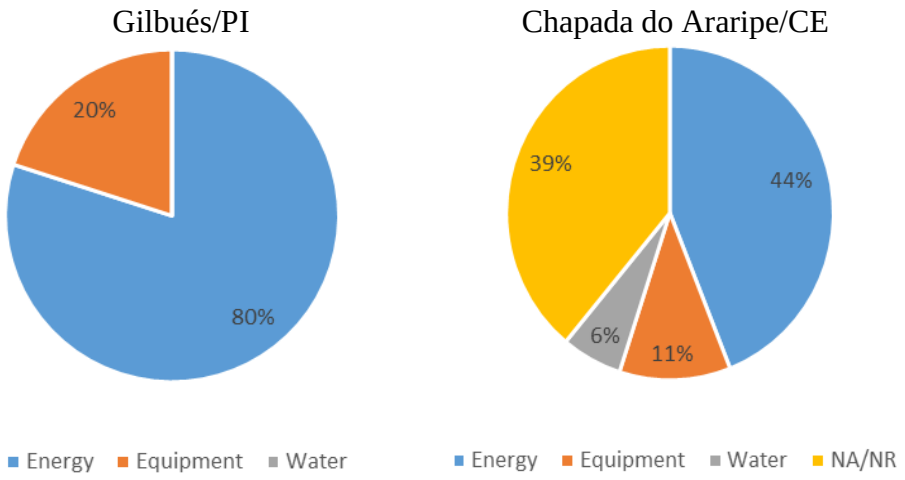


Figure 7: Source of irrigation costs

Seridó/RN Juazeiro/BA

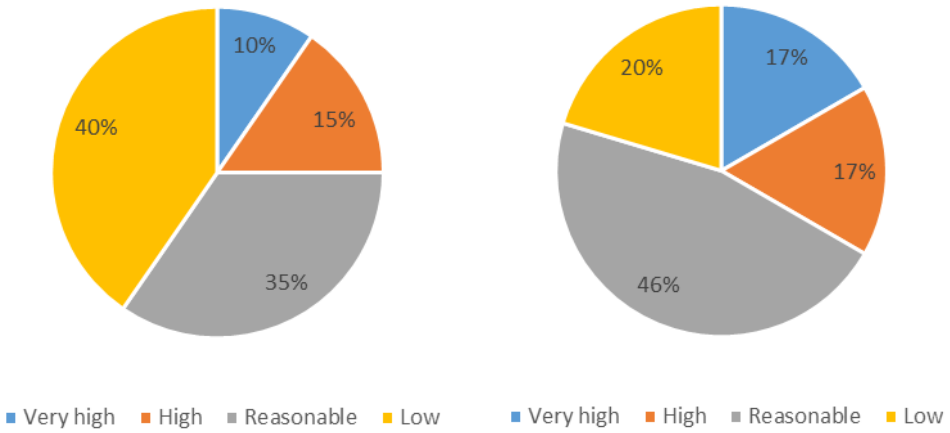


Figure 8: Cost of energy in final production cost

The objective of the two aforementioned questions combined gives us an indication of the participation of cost of energy in the final cost of production. In order to capture the same information for the cases of Juazeiro/BA and Seridó/RN, the two questions were merged and the family farmers were asked: What is the cost of energy in the total production cost? *(Se faz irrigação: Custo da energia no custo total da produção*?).

In the case of Seridó/RN, a quarter of the respondants indicated that energy was high or very high, while the majority indicated that the cost was reasonable or low, as shown in Figure 8. In Juazeiro/BA, a larger proportion (approximately one third) of the farmers indicated that energy was high or very high in their final production costs.

The survey which was used in the Gilbués/PI case study included an additional question regarding the perception of the cost of electricity within their family budget (*Como avalia o custo da energia no orçamento familiar?*). 41.3 percent of the population considered the cost of energy to be high or very high, as shown in Figure 9.

One of the main drivers for the perception of the cost of electricity is the electricity tariff. Although rural tariffs are lower than other tariffs in Brazil, there is a variability between distribution companies as per the data from the National Electricity Regulator, ANEEL, shown in Figure 10. For each of the cases considered, there is a different distribution company that exclusively operates within the state; COELBA (Bahia), COSERN (Rio Grande do Norte) were both privatized in 1997, COELCE (Ceará) was privatized a year later (ABRADEE, s.d.), while CEPISA is a subsidiary of Eletrobrás, and distributes electricity within the state of Piauí.

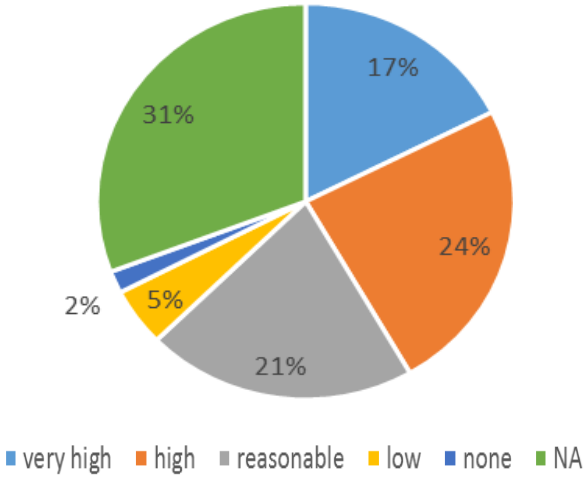


Figure 9: Cost of energy in family budget

Figure 10 shows that rural electricity tariffs in Piauí are 42 percent higher than those in the state of Ceará, as well as 27 percent higher than the average for the Northeast of Brazil. In this context, is not very surprising that the majority of farmers interviewed in Piauí indicate energy as the main cost of irrigation as well consider the overall cost of energy in their family budget as high or very high. According to the study by Bandeira on the regional differences in electricity tariffs in Brazil as well as the quality of supply (i.e. frequency of blackouts or service interruptions) there is a general trend in

which higher electricity tariffs and lower quality services exist in the less developed regions of the country. He concluded that this creates a perverse economic signal, favoring development in areas with already higher indices of development and that this is contrary to the vary fundamental objective stated in the Brazilian constitution (art. 3º, part III), which is the eradication of poverty and marginzalization and the reduction of regional and social inequalities (Bandeira, 2011, p. 12).

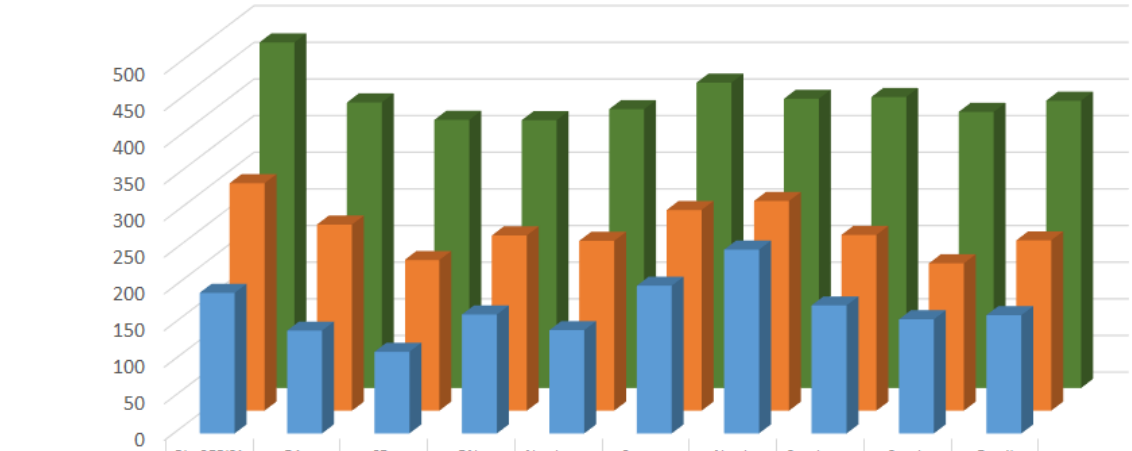
5. Next Steps

Energy poverty in Brazil has been significantly reduced in the past decade with the Light for All (*Luz para Todos*) programme (2003-present), extending the electricity grid to rural and non-rural areas alike. This paper did identify that energy access in the semi-arid region of the Northeast of Brazil is still a challenging issue, which in turn places barriers to agricultural production.

Energy costs were by-in-large identified as the major source of irrigation costs and in PI and CE, while in RN and BA, about one third of respondents considered energy costs of the final production to be high or very high, indicating that energy affordability is also a challenging issue for the family farmers.

The recently released fifth Assessment Report from the Intergovernmental Panel on climate change, IPCC dedicates an entire chapter to climate-resilient pathways, which they explain are: "development trajectories that combine adaptation and mitigation to realize the goal of sustainable development" (IPCC, 2014). In essence, it is necessary to bridge the mitigation/adaptation divide, which is at the very crux of the nexus approach.

Energy is one candidate for such pathways. As previously discussed, energy use in agriculture represents a significant portion of the global energy demand; while at the same time is a major source of GHG emissions. Efforts to employ renewable energy in agriculture is an accepted means of climate change mitigation. Renewable energy can also operate to bridge the mitigation/adaptation divide, especially within the climate-energy-water nexus; **"**Improving delivery of affordable, reliable energy services to rural communities is critical for helping them develop human and economic capacity to adapt in the face of a changing climate" (Casillas and Kammen, 2010).



	PI - CEPISA	BA - COELBA	CE - COELCE	RN - COSERN	Northeast	Centre-west	North	Southeast	South	Brazil
Rural-Irrigation Tariff	191.83	140.26	111.4	162.25	140.92	201.56	250.76	174.59	155.75	161.31
Rural Tariff	310.36	253.97	205.57	239.09	231.74	273.8	286.16	239.9	201.08	232.38
Residential Tariff	471.5	389.55	365.79	365.34	380.36	416.52	394.56	397.06	376.71	392

Figure 10: Electricity Tariffs ($R/MWh) by Distribution Company, Consumer Type and Region, 2013 (ANEEL, 2014)

Particularly, the Northeast of Brazil is a region that could benefit from energy policies that adopt a nexus approach; ensuring just and equitable access to renewable electricity. Solar and wind resources in this area are known to be abundant (Amarante et al., 2001) (Pereira et al., 2006), yet are not taken advantage of in any significant manner by farmers. Decentralized renewable energy can provide obvious mitigation and adaptive benefits (Venema and Rehman, 2007) that have the potential to enhance the co-existence of family farmers in Brazil's semi-arid to the resources available, namely through the use of solar energy. Many questions regarding the manner in which family farmers could take advantage of such technologies remain unanswered. Possible options for the deployment decentralized electricity generation within the adaptation-mitigation nexus will be the object of further research.

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