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ORIGINAL PAPER

Residual biomass energy potential: perspectives in a peripheral region in Brazil

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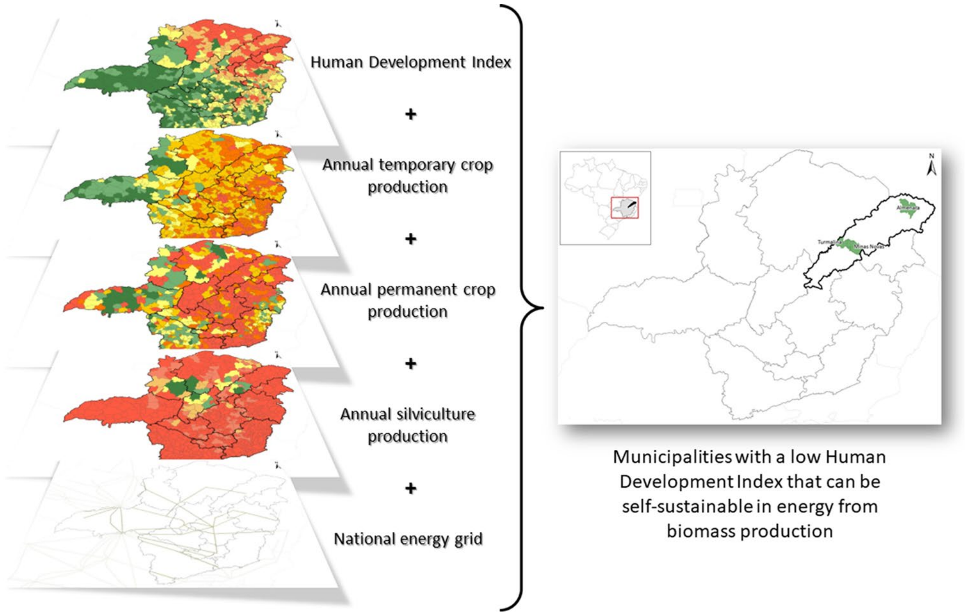
Abstract

As a part of the United Nations new sustainable development agenda, renewable energy was one of the goals identified for the sustainable use of our planet. Previous studies on biomass energy production in Brazil have shown promising results as a renewable energy source. This paper highlights opportunities for power generation from biomass in the less developed regions of Brazil. Such opportunities create new energy generation possibilities in a country that already has an enormous rate of agricultural production, enabling access to energy and therefore increasing quality of life, optimizing available resources and decentralizing the energy system. This paper aims to evaluate the regional potential of energy generation in municipalities with a low Human Development Index. The methodological approach is divided into four steps: (1) the selection of the municipalities to be studied, (2) an assessment based on the production data from the selected municipalities, (3) the calculation of energy demand and a (4) comparison of the biomass energy potential and demand. Our results indicate that three small municipalities in the Jequitinhonha Valley (Minas Novas, Turmalina and Almenara) have the potential to be self-sustainable in energy production. In accordance with the UN recommendations, this potential should be explored more thoroughly.

Graphical abstract



Keywords Biomass energy · Sustainable development · Energy potential · Energy security

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Extended author information available on the last page of the article

Introduction

In September 2015, the United Nations released a set of 17 goals as part of a new sustainable development agenda. The agenda focused on ending poverty, protecting the environment and ensuring prosperity for all by 2030. The objective was to reinforce the urgency of taking action in order to change the status quo. The topic of renewable energy is mentioned in goal 7, which aims to ensure access to affordable, reliable, sustainable and modern energy for all (United Nations 2015). Hence, the development of new technologies for energy generation is not only a topic of interest but is one of the goals for the sustainable use of our planet's resources.

Much research has been carried out in the search for cleaner and cheaper energy sources in many different countries. In order to reduce the emissions from energy generation, Panepinto et al. (2015a) explored planning possibilities for biomass energy production in Italy. They took into consideration the local demand, different types of available biomass as sources, the overall emissions and the consequent air pollution. The paper had positive results concerning the reduction in GHG emissions and the carbon footprint. Chakma et al. (2016), discussing the possibilities for bioenergy from rice residues in India, achieved favorable results in terms of energy prices and GHG emission reductions. The method provided a viable solution for the country's energy security and assisted in impact mitigation, without compromising the socioeconomic growth of the country's development. With the aim of finding ideal regions for the development of biomass energy initiatives with small impacts on the environment in Brazil, Ribeiro and Rode (2016) explored the capabilities of the country for energy production conserving and respecting the environment, as well as encouraging the creation of decentralized energy systems. Through GIS analysis, it was found that the lack of investments in technological improvements and changes in the system status quo were the determining factors for the delay in the development of the energy sector. Lillo et al. (2015) in Peru, Panepinto et al. (2015b) and Palmas et al. (2012) in Italy, Skoulou et al. (2011) in Greece, Palmas et al. (2015) in Germany, Turrado Fernández et al. (2016) in Spain, Batidzirai et al. (2016) in South Africa, Bhattacharyya (2014) in Southern Asia and Mayer et al. (2015) in Brazil are just some examples of the many researchers around the world that use different approaches and techniques to explore renewable energy opportunities.

Around 65% of Brazil's total electricity is produced by hydropower in a centralized system (EPE 2018). Even though there is a consensus in the scientific community about the damages caused to the environment and riverine communities by major hydroelectric projects (Hanna de Almeida Oliveira et al. 2016; Winemiller et al. 2016; Nobre et al. 2016; Voivodic and Nobre 2018; Castro-Diaz et al. 2018; Moran et al. 2018), it continues to be the main energy source for expansion of the country's electric system. The main geographical foci for this development are the Amazon and the Cerrado (Brazilian Savannah) (Ferreira et al. 2014), two large megadiverse biomes that suffer great pressure from agriculture, livestock farming and logging. Recent corruption scandals involving the construction of hydroelectric plants raise the question of whether the motivation for such construction is actually the generation of energy for the population or simply a way to divert public money and to attend particular financial interests (Voivodic and Nobre 2018; Moran et al. 2018).

In Brazil, discussions on renewable energy have not yet been a large focus, even though it could have a desirable positive impact on the country's GDP, employment and emissions (Lucchesi et al. 2017). Biomass used to be the primary fuel source used by human populations and still is for almost ten million people in Brazil today. Many Brazilians still rely on traditional biomass energy sources for cooking, with the majority of these people living in poor municipalities far from urban areas (Coelho et al. 2018). However, such biomass cannot be considered as a renewable source as the wood comes mainly from deforestation (Coelho et al. 2014). Additionally, hydropower energy in Brazil remains an untrustworthy source due to the risks of droughts all over the country, which is aggravated by climate change (Hunt et al. 2018; Moran et al. 2018). Natural gas thermoelectric plant is still seen as the emergential energy source in moments of water scarcity (Corrêa da Silva et al. 2016; Zurn et al. 2017). It is an element that should bring security to the country's energy supply, but instead, ends up not only leaving the system more polluted, but also leaving it more fragile as many of these thermal power plants were built in the 1960s and 1970s. With obsolete machinery, they operate at low efficiency with constant forced outages that increase energy costs (Corrêa da Silva et al. 2016). The alternative, thermoelectric energy, also intensifies inequalities within the country, as it is a more expensive type of energy and financially unattainable for the poorer population (Hunt et al. 2018).

Less developed areas are often forgotten by national politics in regard to development measures. Growth and funding continually goes to the same regions and people. In the most recent UN Human Development Report, Brazil was in the 79th position in the development ranking, out of a total of 189 countries (UNDP 2017a). However, when the index considers social inequality, Brazil is 19 positions lower. This is below the average for Latin America and the Caribbean, starkly illustrating the development issues facing Brazil. Also used to measure inequality, the Gini index does not improve the Brazilian situation. The country is ranked among the 10 worst inequality grades in the world at the 146th position, the worst performance from any Latin American country (UNDP 2017b). Inequality reduction in Brazil has stopped. The distribution of income has stagnated, poverty has returned, and the equalization of income between men and women, and blacks and whites has receded. These are undesirable setbacks for a country whose majority is made up of the poor, blacks and women (Oxfam Brasil 2018).

An extensive review of the connection between electrification and the development of rural areas by Cook (2011) reveals that this association may not always be correct. However, electrification can lead to investments in infrastructure and education, with greater chances for expansion in agricultural activities, entrepreneurism and savings. Therefore, the impact of power generation in some areas is not only related to income, but also to better education opportunities, health care and gender equality, as it is often female employment that is positively affected by access to electricity. To guarantee that such benefits are also reached with the shift to sustainable energy would mean that the country meets many of the goals of the UN sustainable development agenda.

An online search, concerning renewable energy production in Brazil, revealed new initiatives in wind energy, biogas from manure and small hydropower units. However, renewable biomass energy production is not well developed in this country (ANEEL 2008). Initiatives have been conducted almost exclusively by the private sector, by sugarcane companies aiming to reduce their electricity consumption (ANEEL 2018), by rice producers associations (Mayer et al. 2015) or by research institutes (Coelho et al. 2005; Coelho 2009). Brazil is a country that has always relied upon primary products to sustain itself. Pau-Brasil, coffee, cotton, rubber and iron are some examples of what has been produced since the arrival of the Portuguese (Furtado 1965; Rego et al. 2006). The general mind-set is that Brazil should supply primary materials for industries in developed countries, then import the more expensive end product or, alternatively, industrialize a product using imported technologies (Furtado 1974). Neither option contributes to the type of development that could bring a real improvement to the country.

The poorer regions in Brazil that rely on agriculture for a local market tend to diversify their production. The residues from agriculture are commonly left in situ to fertilize the soil or are discarded. Even though it may not be the main objective of the plantations, the residues from the cultivations could instead be used to generate energy. This would thereby bring more opportunities to the local population and not compete with food production for land. Previous studies on biomass energy production in Brazil concluded that this option appears promising. In the Brazilian Atlas of Bioenergy (Coelho et al. 2012), for example, the authors present a study that covers the entire country. They considered energy production based on residues from agriculture, silviculture activities, liquid swine sewage and solid urban waste in sanitary landfills. The results were presented on maps with potentials for the entire country and different scenarios of conversion efficiency.

In 2014, the Energy Research Company (EPE) published the Rural Residues Energetic Inventory (EPE 2014) with the main objective of assessing the energy potential of residues from agriculture, livestock and agroindustry. The report presented the specific sources in great detail, providing the production data and the potential waste production. Different conversion technologies were discussed and presented in regard to the technical potential for energy and biomethane production. They estimated a potential of 48 million toe[1] from agriculture and livestock residues.

The BREA Project (Biomass Residues as Energy Source to Improve Energy Access and Local Economic Activity in Low HDI Regions of Brazil and Colombia) was a joint effort between researchers from Brazil and Colombia, which resulted in a very comprehensive data set on energy generation from residues. The main objective of the project was to "develop a better knowledge of energy requirements for productive purposes among poor households in urban and rural areas of Brazil and Colombia (many of them in isolated regions), which could allow inputs for targeted policy interventions" (GBIO et al. 2015, p. 23). The methodology included conversion technologies, scenarios, policies, potentials and barriers in regard to bioenergy development for 32 municipalities in the Amazonian region.

This paper presents the opportunities for power generation in the less developed regions of Brazil. Such opportunities include access to and application of the technology, increasing people's quality of life, optimizing available resources, fostering a decentralized energy system and exploring new energy generation possibilities in a country with an enormous rate of agricultural production. The main objective of this paper is to evaluate the regional potential of energy generation in municipalities with a low Human Development Index (HDI), where it could positively impact people's life.

Materials and methods

The methodological approach is divided into different steps (Fig. 1). The first step was to select the municipalities. Then, an assessment based on the productive data from the selected municipalities was conducted, with the aim of collecting the data needed for estimating the biomass energy potential. The

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[1] Tons of oil equivalent, 1 toe = 11.63 megawatt hour.

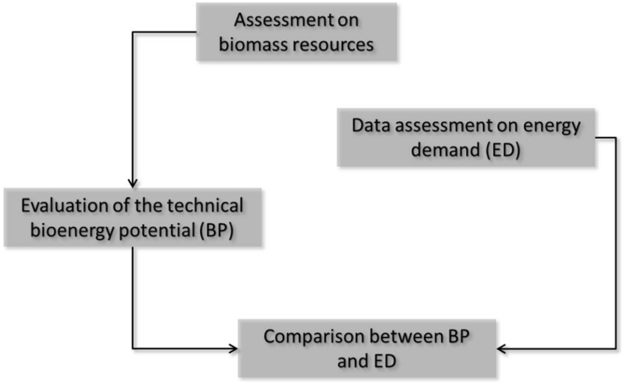


Fig. 1 Methodological approach, adapted from GNESD et al. (2015)

energy demand was calculated and, in a final step, compared to the biomass energy potential.

Selection of municipalities

We sought to identify municipalities where the energy production could help to generate social development associated with sustainability. Using the data obtained by Ribeiro and Rode (2016), information about the Human Development Index (HDI), silviculture production and temporary and permanent crops production was overlaid in a geographic information system environment. In accordance with the findings of the authors and the data availability, the Minas Gerais State was selected for the study.

The HDI (Fig. 2) was classified by ecological-economic state and zoned into five classes: very favorable, favorable, less favorable, precarious and very precarious (Oliveira et al. 2008). By employing this index, we selected municipalities from the Minas Gerais State that were classified as precarious or very precarious.

The second relevant aspect for study site selection was the crop (Figs. 3 and 4) and silviculture production rate (Fig. 5). To estimate the biomass energy production by exclusively using residues, the selected areas needed to have good residue availability in order to make the production viable. For this purpose, 2015 production data from the Brazilian Institute of Geography and Statistic (IBGE) were assessed.

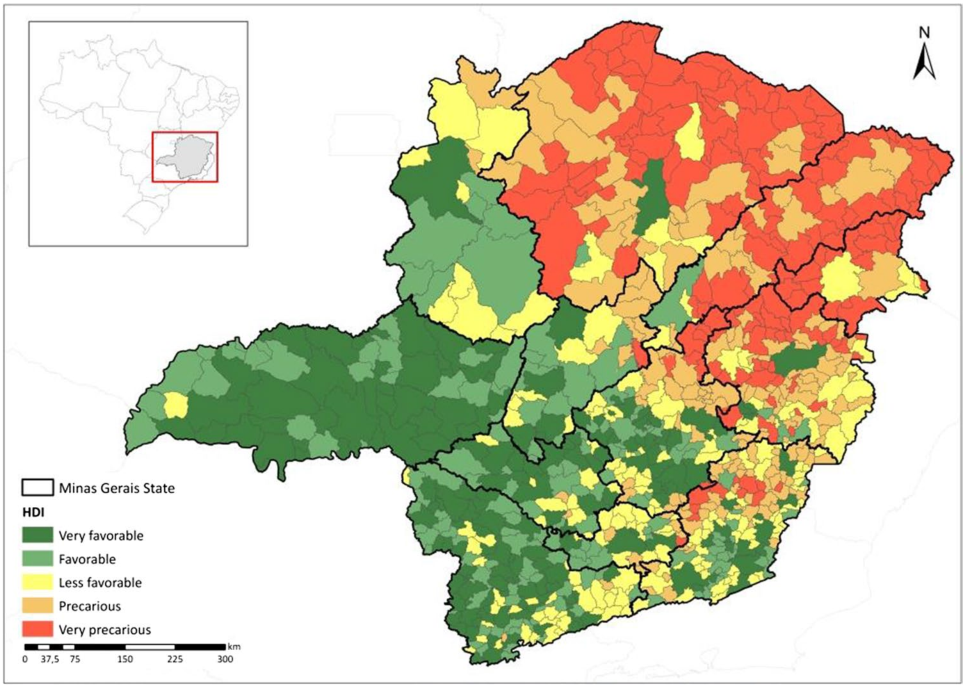
The third factor for selection of the municipalities was the distance to energy grids. Distance is an important factor as we wanted to find areas with no or poor connections to the national grid (Fig. 6), thereby promoting grid decentralization.

Productivity Data Analysis

Data on crop and silviculture production in Brazil are available from the SIDRA platform. For temporary and permanent crops, data for the chosen municipalities were collected on crops that had a production level of higher than 1000 ton/year in 2015. As they were present across the entire state, the three crops chosen were coffee, manioc and sugarcane.

For the silviculture data, we selected data pertaining to the production of eucalyptus charcoal, firewood and wood

Fig. 2 Human Development Index in Minas Gerais State (Oliveira et al. 2008)



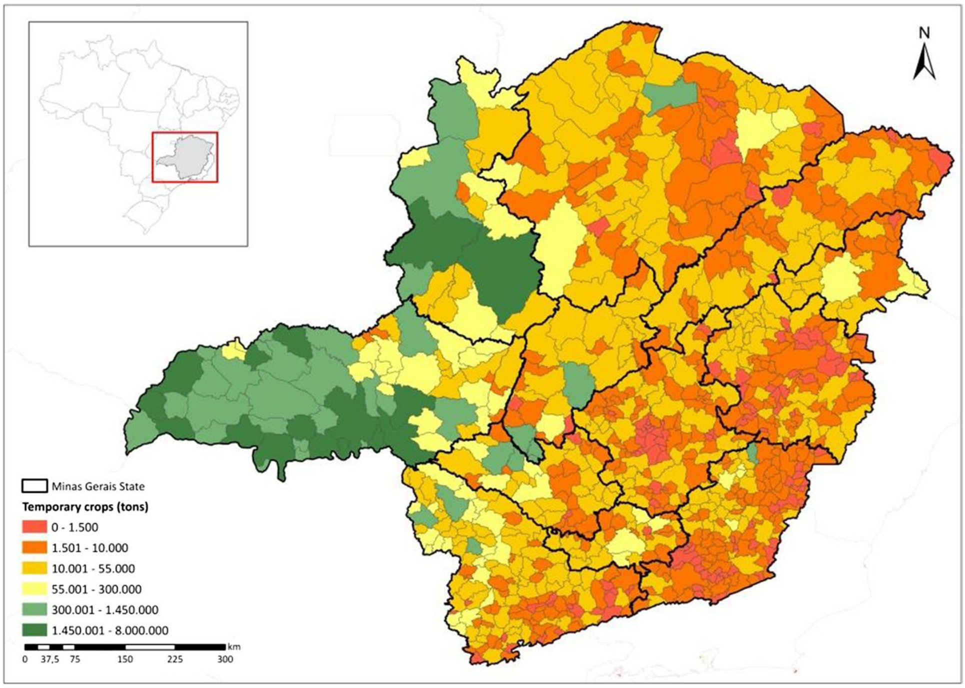


Fig. 3 Annual temporary crop production in Minas Gerais State (SIDRA-IBGE 2015)

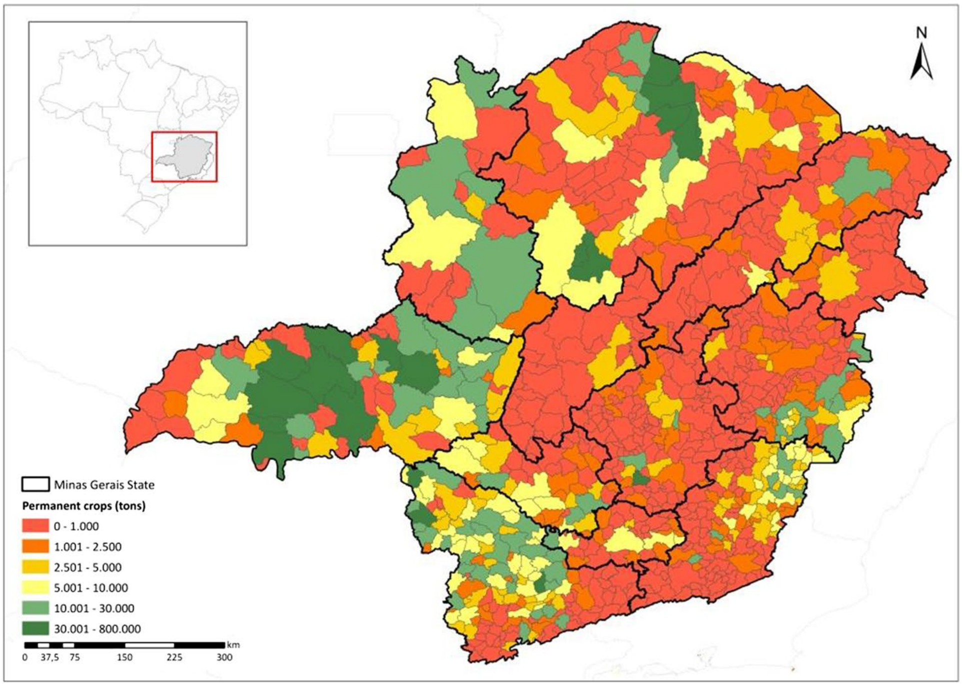


Fig. 4 Annual permanent crop production in Minas Gerais State (SIDRA-IBGE 2015)

in 2014. To ensure the sustainability of the process, data regarding wood products from native vegetation were not considered in this study.

The theoretical potential, or the maximum energy that could be produced with 100% efficiency, was calculated by multiplying the annual production of residues by the lower heating value (LHV) of each crop. The theoretical potential indicates the amount of energy that could be produced with improvement through conversion technologies.

The production data per municipality were organized, and for each product, we calculated the proportion of residues within the production total, or the technical coefficient. We also used the LHV for each crop, making it possible to calculate the potential energy production.

Fig. 5 Annual silviculture production in Minas Gerais State (SIDRA-IBGE 2015)

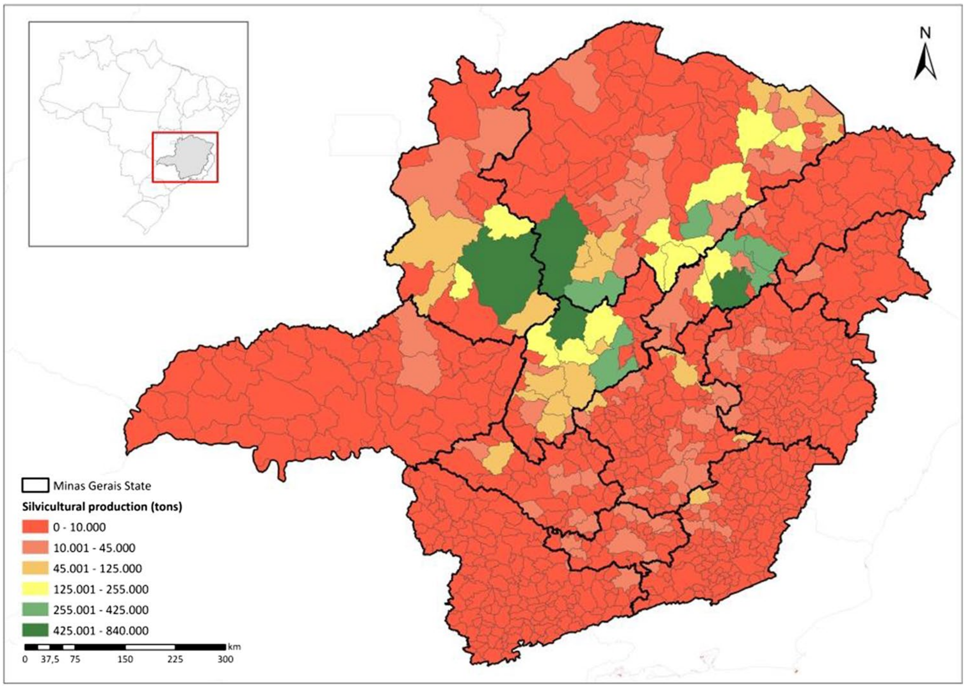
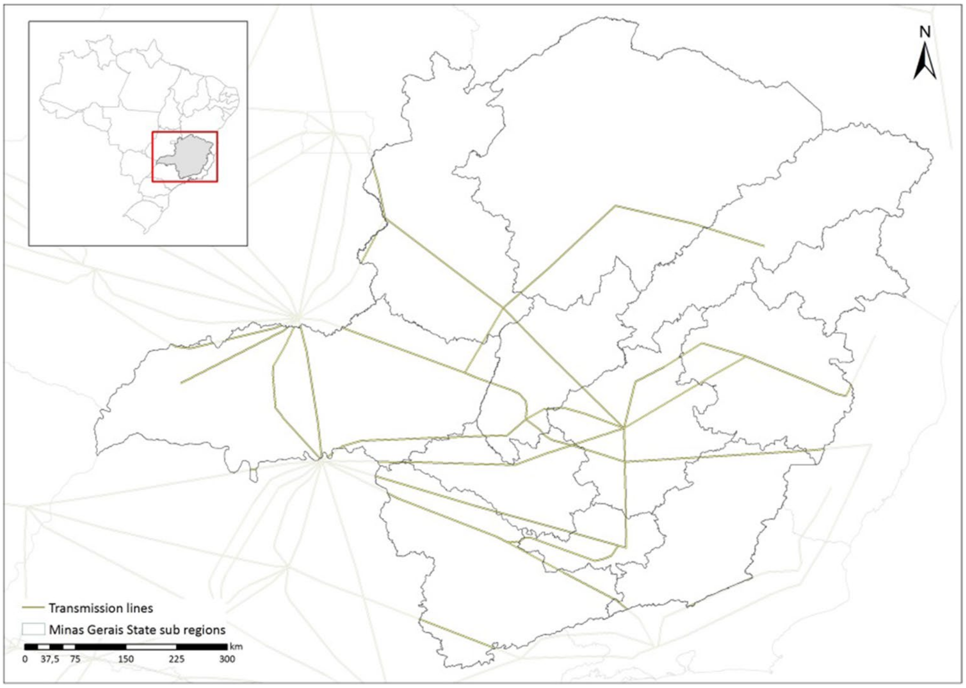


Fig. 6 National energy grid (IBGE; ANEEL 2016)



Application of formulas

To calculate the technical potential or the amount of energy that could be produced, including consideration of any losses during the process, we applied different formulas to different sources. All the formulas were used by GBIO et al. (2015) for the BREA Project.

- **Crops**: The conversion efficiency adopted for the residues was 15%, with low thermodynamic yield—20 bar boiler compound systems, atmospheric condenser turbine (GBIO et al. 2015).

$$\text{Potential (MW/year)} = \frac{\left[\left(\text{Crops}_{\text{tons}} \times \text{TC}\right) \times \text{LHV}_{\text{kcal/kg}} \times 0.15\right]}{\left(860 \times 8322_{\text{hours}}\right)}$$

where:

- $\text{Crops}_{\text{tons}}$: total of harvested crops in a year
- TC: technical coefficient
- LHV: lower heating value
- 0.15: 15% conversion efficiency
- 860: conversion factor from kcal/kg to kWh/kg
- 8322: working hours per year (considering that the energy would be produced in 95% of the year's hours. This factor converts the results from megawatt hour to megawatts per year).

- **Sugarcane**: As the calculation was made for simple systems, we considered the lower energetic yield of 30 kW/sugarcane tons.

$$\text{Potential (MW/year)} = \frac{\left(\text{Sugarcane}_{\text{tons}} \times 30_{\text{kWh/ton}}\right)}{\left(1000 \times 5563_{\text{hours}}\right)}$$

where:

- $\text{Sugarcane}_{\text{tons}}$: total of harvested sugarcane in a year
- $30_{\text{kWh/ton}}$: energetic yield of sugarcane in cogeneration systems
- 1000: conversion from kW to MW
- 5563: working hours from April to November (considering the harvesting time. This factor is important to convert the results from megawatt hour to megawatts per year)

- **Wood**: The calculation of the potential considered for a conventional steam turbine system (Rankine cycle) with yields of 15%, considering a small-sized system.

$$\text{Potential (MW/year)} = \frac{\left[\left(\text{Wood}_{\text{tons}} \times \text{TC}\right) \times \text{LHV}_{\text{kcal/kg}} \times 0.15\right]}{\left(860 \times 8322_{\text{hours}}\right)}$$

where

- $\text{Wood}_{\text{tons}}$: total of harvested wood in a year
- TC: technical coefficient, proportion of residues in the total yield
- LHV: lower heating value
- 0.15: 15% conversion efficiency
- 860: conversion factor from kcal/kg to kWh/kg
- 8322: working hours per year (considering that the energy would be produced in 95% of the year's hours. This factor converts the results from megawatt hour to megawatts per year)

Demand Calculation

We adopted the energy ladder from Coelho and Goldemberg (2013) to estimate the potential energy demand in the municipalities for two distinctive phases: (1) First phase: basic energy needs (lighting, cooking and heating), which would necessitate about 50–100 kWh per person per year, (2) Second phase: productive uses (water pumping, irrigation, agricultural processes, heating and cooking), which would necessitate about 500–1000 kWh per person per year.

As presented by Coelho et al. (2015), we calculated low and high electricity requirements based on the following formulas:

- First phase (basic human needs)

$$\text{Electricity demand}_{\text{(low)}} = \text{number of inhabitants} \times \text{access rate}_{(\%)} \times 50\ \text{kWh},$$

$$\text{Electricity demand}_{\text{(high)}} = \text{number of inhabitants} \times \text{access rate}_{(\%)} \times 100\ \text{kWh}.$$

- Second phase (productive uses)

$$\text{Electricity demand}_{\text{(low)}} = \text{number of inhabitants} \times 500\ \text{kWh},$$

$$\text{Electricity demand}_{\text{(high)}} = \text{number of inhabitants} \times 1000\ \text{kWh}.$$

For both phases, an average value of electricity demand was measured for the results. This was calculated by taking the mean of the low and high values:

$$\text{Electricity demand}_{\text{(average)}} = \frac{\left(\text{Electricity demand}_{\text{(low)}} + \text{Electricity demand}_{\text{(high)}}\right)}{2}.$$

Results

Selection of the study areas

By combining the HDI, the crop or silviculture production rate and the distance to energy grids, it was possible to select three municipalities: Turmalina, Minas Novas and Almenara (Fig. 7). The first two municipalities were selected due to their high production in temporary (Fig. 3) and permanent crops (Fig. 4), as well as their large amount of silviculture activity (Fig. 5). The region is a supplier of eucalyptus charcoal for the iron industries in western Minas Gerais. Almenara was selected so that the methodology could be tested in a municipality with a larger population and for comparison to the other two study areas.

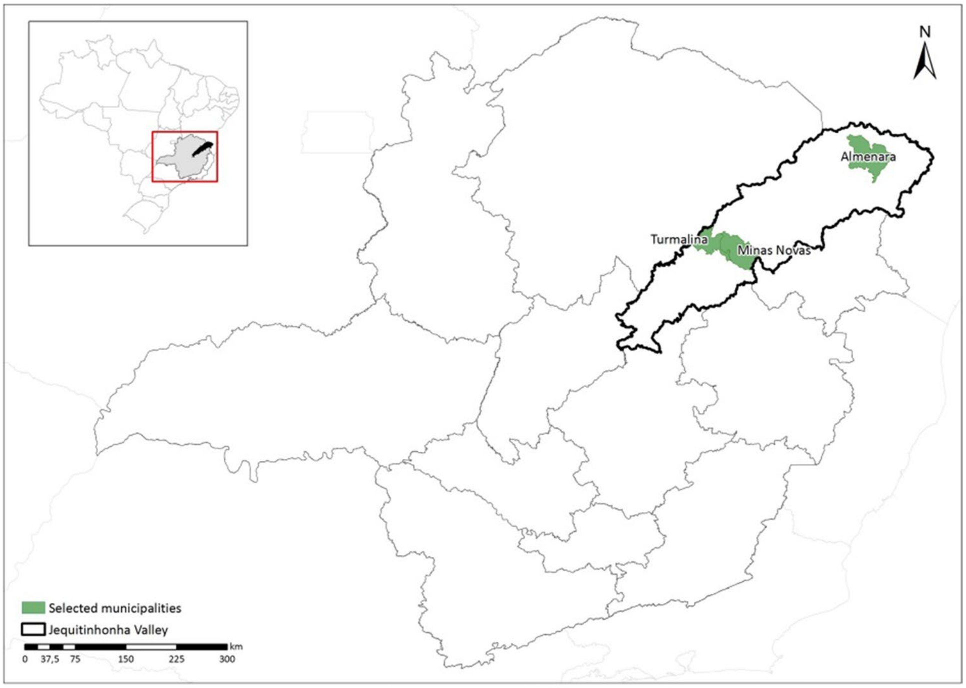


Fig. 7 Selected municipalities (IBGE)

The three municipalities are part of the Jequitinhonha River Valley, an area known historically for its poverty, but which is nevertheless abundant in cultural and natural richness. Eucalyptus plantations were established in the region as part of a strategy by the military government to develop the area through investments, jobs and use of the traditional common collective areas (Ribeiro et al. 2007).

While not attracting as much attention as the Amazon, the Jequitinhonha Valley has nevertheless a great natural and cultural richness. The region has specific and unique vegetation due to the transition of Savanna, Atlantic Forest and Dry Forest (Gontijo 2001). This natural wealth, however, is not associated with the material wealth of the local human population. The Jequitinhonha Valley has a social structure marked by relationships based on clientelism. It is also a place where effective local development measures, which usually do not consider regional potentials in their diverse forms, are not commonly perceived or prioritized by the national or state government. The potentials of these areas to produce biomass energy have never been explored.

Evaluation of the technical bioenergy potential

The *theoretical potential* indicates the maximum of energy that could be produced, not considering efficiency and conversion losses. For now, there is no technology available that could achieve these values. The relevance of the calculation is to show the full potential of the residues from the area and to evaluate which would be the best conversion technology to be applied.

The two municipalities with wood production had significantly higher theoretical values for energy production (Table 1). In Almenara, the municipality with the lowest result, the potentiality is stronger with sugarcane and manioc residues. If production with these residues were feasible, the combined energy alone would produce almost three times more energy than Brazil's biggest hydroelectric power station, Itaipu. Itaipu is the second largest hydroelectric dam in the world and generated 103.1 million MWh in 2016 (Itaipu Binacional 2017).

The *technical potential* gives a more accurate estimation of energy potential. A low conversion efficiency was adopted, particularly as this is a cheaper technology that could be applied to the study areas. In Table 2, it is possible to see the capacities of the silviculture residues in the final energy potentials. In both Turmalina and Minas Novas,

Table 1 Total theoretical potential of renewable energy from biomass on the investigated municipalities

	Turmalina kWh/year	Minas Novas kWh/year	Almenara kWh/year
Coffee	79,770,170	2,485,913	2,386,476
Sugarcane	6,636,078	16,590,195	17,696,208
Manioc	1,156,301	4,827,557	23,241,653
Wood	474,644,211	410,009,835	0
TOTAL	562,206,760	433,913,500	43,324,337

Table 2 Total technical biomass energy potential for the selected municipalities

	Turmalina		Minas Novas		Almenara	
	MW/year	kWh/year	MW/year	kWh/year	MW/year	kWh/year
Coffee	1.44	11,963,372	0.04	372,820	0.04	357,907
Sugarcane	0.03	180,000	0.08	450,000	0.09	480,000
Manioc	0.02	173,414	0.09	724,003	0.42	3,485,620
Wood	8.55	71,183,819	7.39	61,490,407	0.00	0
Total	10.04	83,500,605	7.60	63,037,230	0.55	4,323,527

Table 3 Energy demand according to the energy ladder in the selected municipalities

	Inhabitants	% Energy access (2010)	Basic needs kWh/year (average)	Productive uses kWh/year (average)	Power demand (kW)		
					8 h/day	12 h/day	24 h/day
Turmalina	18,055	99	1,340,584	13,541,250	1237	1855	24,733
Minas Novas	30,794	97	2,240,264	23,095,500	2109	3164	42,184
Almenara	38,775	96	2,791,800	29,081,250	2656	3984	53,116

silviculture is responsible for more than 85% of the total bioenergy potential.

Data assessment on energy demand

As shown in Table 3, in the three municipalities, most of the population has access to energy. It was postulated that with a higher rate of energy access, the development of a new sector in the region could increase the income of the population (by reducing the energy prices) and also help to develop a market for the sustainable use of resources, generating new jobs. This would also help guarantee a continued supply of energy. Almenara, the most populated municipality, showed the lowest rate of energy access and the highest demand.

Comparison between the bioenergy potential and the local demand

A comparison of *energy potential* and *energy demand* indicates the following scenarios: For Turmalina and Minas Novas, the crop and the silviculture potentials would be more than enough to supply their energy requirements. For Almenara, a municipality without silviculture industries, the energy potential from crop residues could meet the demands of the population's basic need. However, a gap of more than 24 million kilowatt-hours for a productive scenario would be left.

Discussion

The methodology, applied previously to municipalities in the Amazon (Coelho et al. 2015), presents a feasible approach for the estimation of biomass potential, considering losses involved in the process. Calculations regarding the collection logistics, transport of materials, purchase, installation and operation of a power generating unit and training were not addressed in this paper.

The municipality Turmalina showed the best results. With a strong and diverse range of agriculture production, the municipality also has a large eucalyptus plantation area. Calixto et al. (2009) present a historic review of how the eucalyptus plantations were established in the Jequitinhonha Valley. In the seventies, the military dictatorship government (1964–1985) wanted to stimulate the iron and steel industry, but the lack of coal was an obstacle. To solve this issue, an incentive program was created giving a 50% tax reduction to companies and private entrepreneurs that wanted to invest in the wood plantations. In the Jequitinhonha Valley, those initiatives helped to bring development and national integration. The high plateau areas were chosen for the eucalyptus plantations due to their lack of agricultural capacity and, in most of the cases, their lack of legalized ownership. Those areas were traditionally used as a common exploration area by farmers in the region, mostly smallholdings managed by families (Galizoni 2000). This explains the large amount of eucalyptus in Minas Novas. The municipality's potential corresponds to the establishment of a small hydroelectric dam (ANEEL 2018), with the silviculture residues responsible for the larger potential of energy production.

In Almenara, the picture is different: The agricultural production provides the entire energy potential of the municipality. Due to a smaller silviculture production, it was the only municipality without an adequate potential to meet the productive demand. However, the number of inhabitants in Almenara is tenfold higher and is therefore also a factor when compared to Turmalina and Minas Novas (Table 4). However, as an area with a consolidated cattle activity (Ruas 1998), a study that considers the production

Table 4 Comparison of the technical bioenergy production potential versus energy demand for the investigated municipalities

	Crop residues (kWh)	Silviculture residues (kWh)	Total (kWh)	Production–demand (basic needs) kWh/year	Production–demand (productive uses) kWh/year
Turmalina	12,316,786	71,183,819	83,500,605	82,160,021	69,959,355
Minas Novas	1,546,823	61,490,407	63,937,230	61,696,967	40,841,730
Almenara	4,323,527	0	4,323,527	1,531,727	24,757,723

of energy through manure biogas (as shown in Salomon and Lora 2005, 2009; GBIO et al. 2015) should lead to better results for Almenara.

Almenara is also comprised of a large amount of degraded pastures (SIDRA-IBGE 2015). Other possibilities for energy production could be the recovery of such areas by using native crops and trees with the potential for energy production in an agroforestry system. Previous studies in the same river basin have produced good results for soil and vegetation recovery of degraded areas on small farms (Pereira et al. 2007).

The results also show that silviculture industry is strong in the region. In Turmalina and Minas Novas, these residues alone could fulfill the highest energy demand. In the region, three companies are responsible for 95% of the eucalyptus plantations (Calixto et al. 2009). The same authors point out that one of the main objectives of reforestation (job creation) has not been satisfactorily fulfilled. Dominating 38% of the agricultural land, eucalyptus cultivation occupies around 4% of the workforce. The development of a biomass energy sector in the region may not only lead to improvements in the energy system, but also create local jobs in different sectors of the productive chain (ANEEL 2008). Such effects are shown by Dinkelman (2010) in cases of areas without previous electrification, and by Moreno & López (2008) who analyzed different types of renewable energy jobs in Spain.

It should be noted that all calculations were made taking into account a viable technology for the local area: a cheap technology with low conversion efficiency. Considering that investment into sustainable energy to improve people's lives is not necessarily a lucrative business, together with the current economic downturn in Brazil, environment issues are not priority. The 2018s elections raised international concern for how the new government will conduct its environmental agenda (Tollefson 2018). Without mentioning this subject during the polls, the elected president threatened to leave the Paris Agreement (Escobar 2018), expand the exploitation of the Amazon region and reduce the protected areas. Brazil has already rescinded as host of COP25 in 2019 (Chiaretti 2018; Pontes and Resende 2018). Within this context, a modern and expensive technology with a high conversion coefficient is unrealistic. Importantly, the results for the *theoretical potential* represent the maximum amount of energy that could be generated, for production attainable with the technological development. One of the conclusions of the BREA report (GBIO et al. 2015) is that Brazil needs the know-how to develop the biomass energy sector, if economically viable. Obtaining a result that indicates that municipalities can sustain themselves through the generation of energy from agricultural residues, using cheap technology, indicates that there is space for even more improvement.

As highlighted by Lillo et al. (2015), the chance of success, for individual or micro-grid projects in communities, is directly related to the communities' demand for those projects. Even though the municipalities studied here do not actively have this demand, they are examples of areas where the power production could improve income and life quality. Following the recommendation of Panepinto et al. (2015b), the acceptance of the communities involved emerges as a necessary next step for the implementation of projects for bioenergy generation.

Conclusions

Brazil presents itself as a country with an energy matrix centered on hydroenergy. Having faced cyclical periods of drought, the alternative for times of lack of water is the natural gas-fired thermoelectric plants. This goes against the current reduction in GHG emission recommendation, adherence to which is essential for the planet to achieve emission reduction targets. There is an urgent need for investigation of new possibilities for electric energy generation that promotes environmental sustainability, a situation aggravated by the current context of climate change.

Conducting an investigation on the potential for energy production in Brazilian low HDI regions indicated that three small municipalities can be self-sustainable in energy from biomass production. Even when applying low conversion efficiency on waste, it is possible to produce enough energy to meet the demand of small townships by using silviculture and agricultural residues. As the focus of the study was regions with low human development indices, this study presents a possibility for clean development and new sources of income generation for regions that should be targeted by local development policies.

The success of biomass energy production from agriculture residue enterprises depends on more than just energy efficiency. It also depends on, for example, logistics, team training, operational costs and equipment acquisition. In accordance with UN recommendations, this potential should be explored more thoroughly. Considering that the dominant discourse for increasing the energy capacity in Brazil is based on hydroelectric potential, the findings of this paper indicate that there are indeed other possible ways for such increases, bringing to light a possible new energy path.

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