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RESIDUAL ESSENTIAL IN THE MICRO-REGION OF DOURADOS (MS): ASSESSMENT AND AVAILABILITY FOR ENERGY IN AGRICULTURE THERMAL CONVERSION

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ABSTRACT: This research presents results of the assessment of solid biofuels (residual biomasses from agricultural crops) in the state of Mato Grosso do Sul, in the period 2007-2012, for energy in agricultural uses. It is pointed out the available quantity, its geographic location at micro and meso regions and energy conversion potential. The methodology is based on a survey on municipal agricultural production of the Brazilian Institute for Geography and Statistics (quantity and local availability, per year) followed by determination of the amounts of agricultural assessed residues, and then applying equations from the literature to estimate the amount of energy (J) and power (kW) obtained from the thermal conversion of residual biomasses. Results are presented for three residual biomasses from agricultural crops (corn cobs, rice husk and sugarcane bagasse) with cartograms for all micro regions at the state of Mato Grosso do Sul, graphics for quantification in the cities where crops production occurs and a table for total energy obtained by conversion processes. For the whole state of MS, Dourados micro region was identified as the most promising for energy in agriculture with three main cities (Dourados, Rio Brilhante and Maracaju), by solid biofuel availability to provide about 11% of the total electrical energy consumption in 2014.

KEYWORDS: renewable energy, solid biofuels, combustion, torrefaction, powerplants.

INTRODUCTION

Energy is essential to human life and there are many ways of obtaining it for application and uses. Around 86% of the energy converted/produced in the world in 2011 came from non-renewable sources like coal and oil (typical fossil fuels) which greatly contributes to environment global warming (IEA, 2011). After the industrial revolution age, there was a growth in the use of these fossil fuels and this was the main cause of about 30% in CO_2 increases in the atmosphere, and strongly attached to global temperature issues (HINRICHS et al., 2015). Energy in agriculture and power generation, both from renewable energy sources are possible by using, for example, biomass as solid fuel.

Bioenergy is the energy obtained from biomass conversion (SANTOS et al., 2012), and biomass is broadly related to any organic matter from vegetal/animal origin in biological processes, as photosynthesis, as well as materials originated from plant or animal (DU et al., 2015). Hence biomass presents regularly in nature, as in a cycle, not limited in time, so it is considered renewable. Biomass for energy purposes corresponds to 30% in Brazil and China, 45% in India, 10-15% in South Africa and Mexico, and reaches 90% in other countries in Africa. It represents 13-14% in the world, and reaches 33% in developing countries (ROSILLO-CALLE et al., 2005).

In Brazil, main residues from biomasses came from: vegetal (ex: agricultural crops), animal (ex: swine manure), planted forests (ex: Eucalyptus), urban solids (ex: food waste) and industrial (ex: sugarcane industry), according to CORTEZ et al. (2008). Residual biomass consists of waste recovery, for energy usage purposes, from agricultural and/or industrial activities, as sugarcane and seed crops as rice and soybean, as well as Eucalyptus forest (BRAND, 2010); all those existing in the state of Mato Grosso do Sul. That can contribute to decrease the use of fossil fuels while increasing the use of renewable energy sources. Furthermore, biomass is environmentally friendly,

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considering CO_2 reduction in the atmosphere and mitigation of greenhouse gases (FERNANDES & COSTA, 2010).

Considering that there are few studies in the literature on Brazilian regional availability of biomass for energy in agriculture, this study aims to: i) Identify main micro/meso regions in Mato Grosso do Sul for biomass availability; ii) Quantify residual biomass from agricultural crops based on literature methodology; iii) Energy potential assessment of thermal conversion, from raw data from 2007 to 2012.

MATERIAL AND METHODS

The geographic area under analysis in this paper is the state of Mato Grosso do Sul (MS), pointing out main agricultural crops that are cultivated in its 4 macro regions (Figure 1a) or 11 micro regions (Figure 1b). The micro region identified as number 7 is “Dourados”, and consists of 15 cities (IBGE, 2014): Amambai, Antônio João, Aral Moreira, Caarapó, Douradina, Dourados, Fátima do Sul, Itaporã, Juti, Laguna Carapã, Maracaju, Nova Alvorada do Sul, Ponta Porã, Rio Brilhante and Vicentina.

(a) (b) (c)

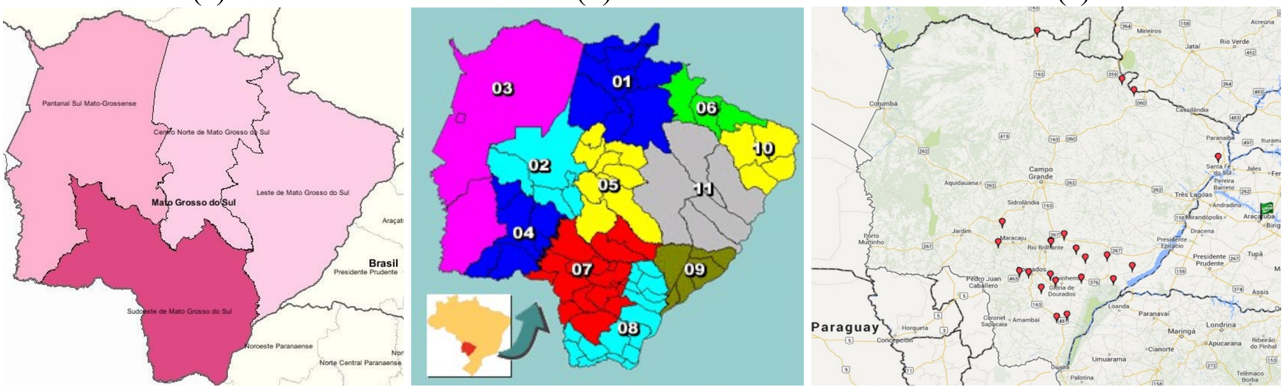

FIGURE 1. Mato Grosso do Sul cartograms: a) 4 Meso regions; b) 11 Micro regions; c) Sugarcane powerplants.

In 2014 there were 22 sugarcane powerplants in MS, 17 of them are located at the same geographic micro region (7 in “Dourados), see Figure 1c. Eight of those powerplants operating in cogeneration thermodynamic cycles, providing thermal and electrical energy. The state of MS exported 700 $GW_{electric}$, which corresponds to 20% of the total amount of energy consumption in the whole state.

Production data for *in natura* crops (rice, corn and sugarcane) were obtained from PAM - Municipal Agricultural Productivity at IBGE - Brazilian Institute of Geography and Statistics database (IBGE, 2014). Cartograms and spreadsheets were generated grouping raw data along 2007-2012, allowing identification and quantification of main agricultural products and cities where it occurs. Energy potential assessment of residual biomass from forest and agricultural residues, considering GIS – Geographic Information Systems, can be considered when IBGE data are not available (VASCO & COSTA, 2009; FERNANDES & COSTA, 2010).

Methodology to estimate the conversion of agricultural waste (residual biomass) into thermal energy has been adapted from the one proposed by the National Reference Center on Biomass (COELHO et al., 2012). Equation (1) is applied for residual biomass from rice (husk), and authors are also considering in here also for corn (cobs):

$$E_{potential}(kW/year) = \{[(T.r).LHV.\eta.1000]/(8,322)\}/3.6 \quad (1)$$

where,

$E_{potential}$ – amount of energy that can be obtained, kW/year;

T – annual production of raw material (grain for corn or paddy for rice), ton;

r – waste to *in natura* ratio weigh, %;
LHV – low heating value, MJ/kg, and

η – energy conversion efficiency in the power generation process, %.

It was considered the full availability of residual biomass for a design power plant, thus operating occurs in 95% of annual hours, resulting in 8,322 h/year. Process efficiency was considered the lowest and simplest available, that is η =15% considering lower thermodynamic efficiency based on a 20 bar steam boiler, according to COELHO et al. (2012). Conversion to International System of Units (SI – *Système Internacional d´unités*) is obtained by multiplying 1,000 and dividing by 3.6. Other higher efficiency technologies for solid biofuels conversion, i.e., biomass into energy are available in the literature, in order to increase the added value of energy. Biomass gasification, for instance, obtains gaseous biofuel from residual biomass resulting in higher HHV – High Heating Value, in kJ/kg or kJ/m³, (SÁNCHEZ, 2010).

Equation (2) is applied for residual biomasses from sugarcane, where the selected conversion process provides 60 kWh/ton and 5,563 h/year of operation (COELHO et al., 2012). Table 1 shows the parameters considered in both equations.

$$E_{potential}(kW/year) = [(T.r).60\,kWh/ton]/(5{,}563) \tag{2}$$

TABLE 1. Parameters for residual biomass and energy assessment in eqs (1) and (2).

Raw Material	T (ton)	r (%)	LHV (MJ/kg)	η (%)
Rice	Annual	30 (1)	14.14 (1)	15 (2)
Corn	production	18 (6, 7) or 20 (5)	16.79 (6) or	15 (2)
	(2007-2012)		17.34(3)	
Sugarcane		30 (4)	-	-

[1](COELHO et al., 2000); [2](COELHO et al., 2012); [3](PAULA et al., 2011); [4](OSAKI, 2014); [5](CASTRO & PEREIRRA JR., 2010); [6](DU et al., 2015); [7](ZIGLIO et al., 2007).

RESULTS AND DISCUSSION

Rice husk as residual biomass

Raw data collected corresponds to the amount of paddy rice produced from 2007-2012 in MS. As shown in the cartogram at Figure 2a, main production cities in 2012 (and previous years) are located in "Dourados" micro region, and from those, six cities had zero paddy rice production in the years under evaluation, and just nine cities are indicated in Figure 2b.

(a) (b)

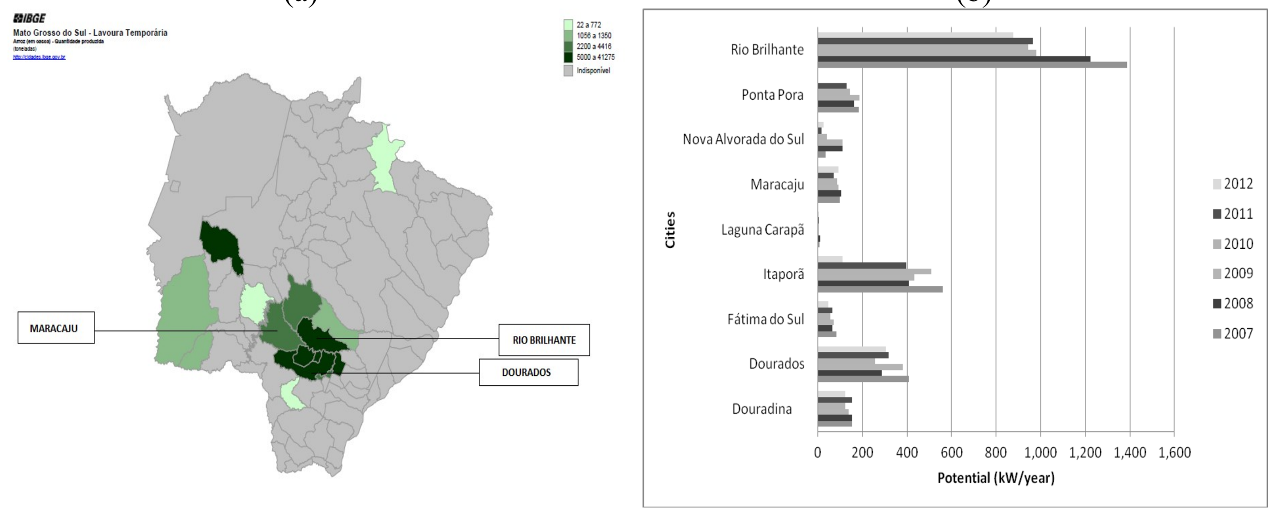

FIGURE 2. Rice and husk data: a) Cartogram for paddy rice annual production in MS (2012); b) Energy/Power potential from rice husk to energy conversion in "Dourados" micro region (2007-2012).

As indicated in Figure 1a, rice production in "Dourados" micro region corresponds to 65.5% of production in the state of MS, standing out three cities: Rio Brilhante, Itaporã and Dourados. It is worth to mention that there was a decrease of approximately 44.8% in rice production when comparing the year 2012 to 2007. This occurred because in many regions, where rainfall has not been enough to fully recover the reservoirs, there is the restriction of the use of water in the rice fields to prioritize the needs of the population. On the other hand, rain-fed crops, normally uses as first planting when opening new agricultural areas are being reduced, since environmentally, it becomes important to achieve the protection of remaining areas of biomes (IBGE, 2014).

In Figure 1b, the three main production sites reached in 2012 $E_{potential}$ of 1,400, 600 and 400 kW/year, considering only the combustion of residual biomass from rice husk. Together it corresponds to about 1,295 kW/year. It is noteworthy that the distance between these cities is relatively small (Itaporã and Rio Brilhante are, respectively, about 20 km and 60 km far away from Dourados), which could lead to cooperation in energy production activities.

Corn cob as residual biomass

Corn production in "Dourados" micro region corresponds 55.2% of the total production in the state of MS (Figure 3a), and has been increasing significantly over the last years. In 2012, production increased by about 82% over the previous year and 120% when compared to 2007. According to the methodology applied, Maracaju appears as the largest producer among all, followed by Dourados, respectively, with 149,900 ha (R$ 233 million) and 90,200 ha (R$ 94.6 million). Furthermore, "Dourados" micro region and the state of Mato Grosso do Sul also occupy the 17th and 5th places, respectively, in national corn production ranking.

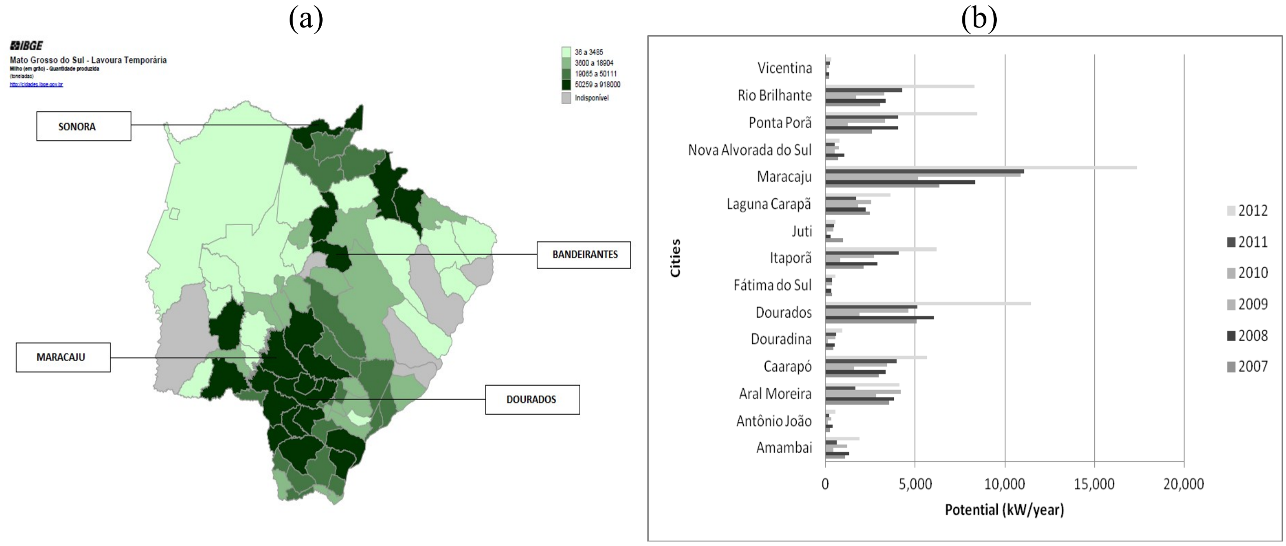

FIGURE 3. Corn and cob data: a) Cartogram for corn annual production in MS (2012); b) Energy/Power potential from corn cobs to energy conversion in “Dourados” micro region (2007-2012).

As indicated in Figure 2b, the four main production cities (Maracaju, Dourados, Ponta Porã and Rio Brilhante) reach in 2012 $E_{potential}$ of 16,000, 10,000, 8,000 and 6,000 kW/year, considering only the combustion of residual biomass from corn cobs, it reaches about 42,000 kW/year.

Again, cooperation in energy power plants for residual biomass is possible, once relatively small distances are among those cities (Maracaju, Ponta Porã and Rio Brilhante are, respectively, about 90 km, 90 km and 60 km far away from Dourados). Even other micro regions in the state of MS, as, for example, numbered as 01, 04, 05, 06, 08 and 09 (in Figure 1b), could have a similar approach, once they appear as medium-high production areas, for example, Sonora (micro region 01, at Mato Grosso borderland). All 15 cities at micro region 07 (“Dourados”) are presented in Figure 3b.

Sugarcane bagasse as residual biomass

Among all 15 cities at micro region 07 (“Dourados”), only one (Aral Moreira) is not presented in Figure 4b, once it did not have sugarcane production area. Among those, Rio Brilhante was the one which produced the majority of sugarcane over the 6 years under analysis (2007-2012), as well as for rice crop. Its sugarcane production peak in 2010 was 6.78 million tons. That city is also the largest producer of sugarcane in the whole state, with 76,690 ha (R$ 294 million in sales). In 2013 national ranking of production, MS reached the 2nd place, and in 2014 was the 3rd largest producer in the country.

(a) (b)

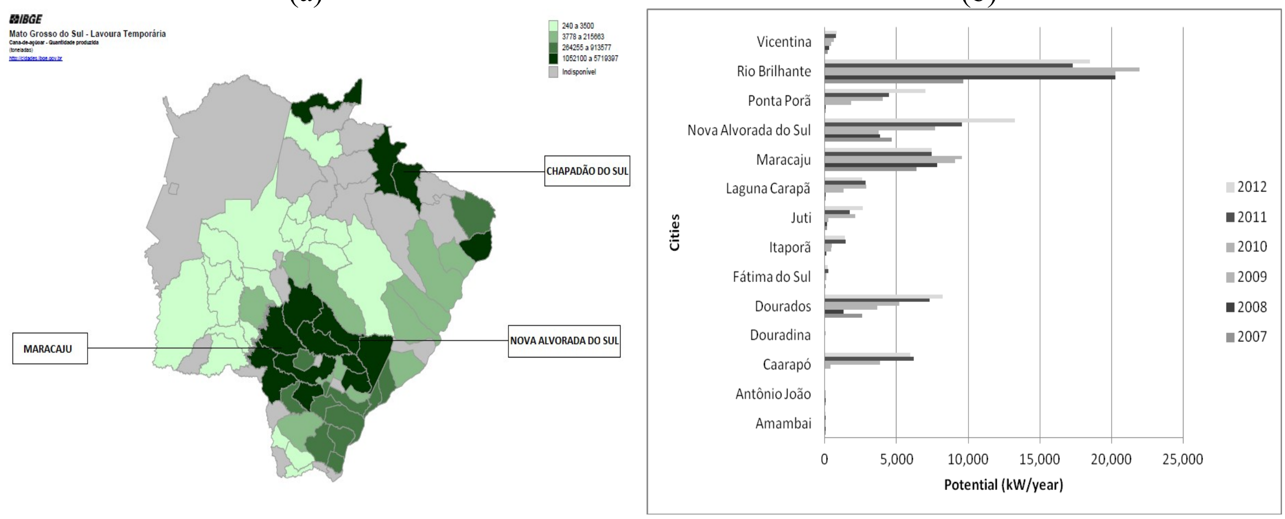

FIGURE 4. Sugarcane and bagasse data: a) Cartogram for sugarcane annual production in MS (2012); b) Energy/Power potential from sugarcane bagasse to energy conversion in "Dourados" micro region (2007-2012).

Five main cities in 2012 are shown in Figure 4b, together they reached about 58,000 kW/year considering only the combustion of residual biomass from sugarcane bagasse. They are Rio Brilhante, Nova Alvorada do Sul, Maracaju, Dourados and Caarapó, respectively, with $E_{potential}$ given by 20,000, 14,000, 10,000, 8,000 and 6,000 kW/year.

Again, cooperation in energy power plants for residual biomass is possible, once relatively small distances are among those cities (Nova Alvorada do Sul, Maracaju, Rio Brilhante and Caarapó are, respectively, about 120 km, 90 km, 60 km and 60 km far away from Dourados). Similar to corn production, sugarcane is also produced in others micro regions in the state of MS, for example, Chapadão do Sul (micro region 06, at the state of Goiás borderland).

Table 2 shows the electrical energy potential (kW/year) for each one of the residual biomasses considered in this study. Annual amounts in the years under analysis and annual mean values are about 89,445 kW/year or 322 $GW_{electric}$ (considering 3,600 hours in a year). Thus, assessment of the three residual biomasses can provide about 11% of the total electrical energy consumption in the state of Mato Grosso do Sul in 2014.

TABLE 2. Total energy generation assessment (kW/year) at the whole "Dourados" micro region.

Residual Biomass	2007	2008	2009	2010	2011	2012
Rice **Husk**	2,915	2,520	2,397	2,67	2,114	1,584
Corn **Cobs**	32,156	38,178	18,490	38,803	38,923	70,830
Sugarcane **Bagasse**	23,774	33,935	41,642	58,674	59,411	68,158
Annual energy generated (kW/year)	59,899	75,884	63,135	100,916	101,723	142,892
Annual mean value	**~89,445 (kW/year) from 536,671 kW in six years**					

This energy potential can be used as indicators for the design and construction of power plants, from public and/or private investment in power generation, in order to have energy in agriculture (solid biofuels) providing city demands for electricity. It also can be considered as future benefits of the producers themselves, increasing added value in their crops, as well as the population with self-sustainable energy provided by them.

In order to facilitate biomass transport from its crops to power plants, a post-treatment to be considered is densification (to obtain briquettes of residual biomass) or torrefaction, both improve

HHV (kJ/kg), the first one by increases in specific mass (kg/m³) and the second one by increases in the energy content itself (kJ/kg) by drying and volatile matter content. These technological solutions are quite discussed in the literature, considering agricultural residues as, residual biomass from coffee crops (PROTÁSIO et al., 2012) or from Eucalyptus residues blended with solid urban waste (GONÇALVES et al., 2009). Another technological route for biomass use as energy is through gasification, as evaluated by DU et al. (2015) for corn cobs gasification.

Corn stalk and cotton stalk, as residual biomass are also examples found in the literature for HHV increases via torrefaction (CHEN et al., 2014). Similar behavior is reported for wheat and barley straw (SATPATHY et al., 2014), with improvements also in biomass grindability and its hydrophobic behavior, thus reducing moisture uptake after torrefaction.

CONCLUSIONS

The residual biomass harnessing of energy in agriculture, in the state of Mato Grosso do Sul, is most promising at Dourados micro region. Quantities determined for corn cobs, rice husk and sugarcane bagasse are significantly higher in three main cities (Dourados, Rio Brilhante and Maracaju), leading with at least two of three residual biomasses studied herein. Considering typical technologies for residual biomass combustion, energy potential in the selected micro region can provide about 11% of the total electrical energy consumption in the state of MS (considering as base 2014).

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REFERENCES

BRAND, M. A. **Energia da biomassa florestal**. Rio de Janeiro: Interciência, 2010. 131p.

CASTRO, A. M.; PEREIRA JR., N. Produção, propriedades e aplicação de celulases na hidrólise de resíduos agroindustriais. Química Nova, São Paulo, v.33, n.1, p.181-188, 2010.

CHEN, Y.; YANG, H.; YANG, Q.; HAO, H.; ZHU, B.; CHEN, H. Torrefaction of agriculture straws and its application on biomass pyrolysis poly-generation. **Bioresource Technology**, Oxford, v.156, p.70-77, mar. 2014.

COELHO, S. T.; MONTEIRO, M. B.; GHILARDI, A.; KARNIOL, M. R. **Atlas de bioenergia do Brasil**. São Paulo: CENBIO, 2012.

COELHO, S. T.; PALETTA, C. E. M.; FREITAS, M. A. V. **Medidas mitigadoras para a redução de emissões de gases de efeito estufa na geração termelétrica**. Brasília, DF: ANEEL/CENBIO, 2000. 222p.

CORTEZ, L. A. B.; LORA, E. E. S.; GÓMEZ, E. O. (Org.) **Biomassa para energia**. Campinas: Editora da UNICAMP, 2008. 736p.

DU, C.; WU, J.; MA, D.; LIU Y.; QIU P.; QIU R.; LIAO S.; GAO D. Gasification of corn cob using non-thermal arc plasma. **International Journal of Hydrogen Energy**, Oxford, v.40, n.37, p. 12634-12649, 2015.

FERNANDES, U.; COSTA, M. Potential of biomass residues for energy production and utilization in a region of Portugal. **Biomass and Bioenergy**, Amsterdam, v.34, n.5, p.661-666, 2010.

GONÇALVES, J. E.; SARTORI, M. M. P.; LEÃO, A. L. Energia de briquetes produzidos com rejeitos de resíduos sólidos urbanos e madeira de Eucalyptus grandis. **Revista Brasileira de Engenharia Agrícola Ambiental**, Campina Grande, v.13, n.5, p.657-661, 2009.

HINRICHS, R. A.; KLEINBACH, M.; DOS REIS, L. B. **Energia e meio ambiente**. 5. ed. São Paulo: Cengage Learning, 2015. 784p.

IBGE - Instituto Brasileiro de Geografia e Estatística. **PAM - Pesquisa Agropecuária Municipal**, 2014. Disponível em: <http://www.sidra.ibge.gov.br>. Acesso em: 1 out. 2014.

IEA – International Energy Agency. **World energy outlook**. 2011. Disponível em: <http://www.iea.org/statistics/statisticssearch/report/?&country=WORLD&year=2011&product=Balances>. Acesso em: 1 fev. 2014.

OSAKI, M. R. **Análise de um modelo de conversão de cana-de-açúcar em vetores energéticos através da integração de tecnologias 1G e 2G – simulação de Monte Carlo para otimização multiobjetivos**. 2014. 246f. Tese (Doutorado) – Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba, 2014.

PAULA, L. E. R.; TRUGILHO, P. F.; NAPOLI, A.; BIANCH, M. L. Characterization of residues from plant biomass for use in energy generation. **CERNE**, Lavras, v.17, n.2, p.237-246, 2011.

PROTÁSIO, T. P.; BUFALINO, L.; MENDES, R. F.; RIBEIRO, M. X.; TRUGILHO, P. F.; LEITE, E. R. S. Torrefação e carbonização de briquetes de resíduos do processamento dos grãos de café. **Revista Brasileira de Engenharia Agrícola Ambiental**, Campina Grande, v.16, n.11, p.1252-1258, 2012.

ROSILLO-CALLE, F.; BAJAY, S. V.; ROTHMAN, H. (Org.). **Uso da biomassa para produção de energia na indústria brasileira**. Campinas: Editora da UNICAMP, 2005. 448p.

SÁNCHEZ, C. G. (Org.). **Tecnologia da gaseificação de biomassa**. Campinas: Ed. Átomo, 2010. 432p.

SANTOS, F.; BORÉM, A.; CALDAS, C. (Ed.). **Sugarcane**: bioenergy, sugar and ethanol - technology and prospects. Brasília, DF: MAPA/ACS: UFV/DEA, 2012. 568p.

SATPATHY, S. K.; TABIL, L. G.; MEDA, V.; NAIK, S. N.; PRASAD, R. Torrefaction of wheat and barley straw after microwave heating. **Fuel**, v.124, p.269-278, 2014.

VASCO, H.; COSTA, M. Quantification and use of forest biomass residues in Maputo province, Mozambique. **Biomass and Bioenergy**, Amsterdam, v.33, n.9, p.1221-1228, 2009.

ZIGLIO, B. R.; BEZERRA, J. R. M. V.; BRANCO, I. G.; BASTOS, R.; RIGO, M. Elaboração de pães com adição de farinha de sabugo de milho. **Revista Ciências Exatas e Naturais**, Guarapuava, v.9, n.1, p.115-128, 2007.