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Determining the Energy Potential of Corn Cobs in Santo Tomas, Pangasinan, Philippines through Remote Sensing

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Abstract— *The continuous rise of fossil fuel prices increases interests on using biomass as an alternative source of energy. There are a number of biomass power plants already in operation in the Philippines, most are using rice husk as fuel. However, there are other biomass available in the country aside from rice husk such as corn cobs. It was learned that harnessing energy from corn cobs is more efficient when carried out in a municipal level. In general, this paper aims to assess and analyze the energy potential of the corn cobs produced in Sto. Tomas, one of the municipalities of Pangasinan which is among the top corn producing provinces in the Philippines. Specifically, it aims to determine whether the determined energy is enough to meet the demand of the whole municipality and identify probable target users at different percentages of availability of the residue. An accurate area of corn plantations in the municipality was obtained from the detailed agricultural land cover map that was generated using remote sensing techniques. Other data that are vital to this study were obtained from fieldwork and literatures. By integrating these data together, the potential energy content of corn cobs in Sto. Tomas was obtained mathematically having a value of about 5.54 GJ. This amount fell short to the municipality's energy demand but may still provide significant contribution if used as power source for some households, providing more beneficiaries rather than as a power source for the other type of connections.*

Keywords— *Corn Cobs: Biomas:, LiDAR: Remote Sensing Renewable Energy*.

I. Introduction

In the Philippines, biomass has been recognized as an alternative source of energy because of its availability and abundance. Due to the increasing demand for electricity, there have been numerous researches regarding the use of biomass, specifically crop residues, as feedstock for energy production. Agricultural crops like rice and corn generates plenty of residues every year which are just left in the field to decompose or are burnt if not used as fuel for fire. Using these residues to supply electricity to some areas will provide economic benefits to the farmers and may lessen the burden of depending to fossil fuels and some other scarce resources and to conserve them for future use.

It was mentioned by Brunner et al. (2011) that harnessing energy from corn cobs must be done locally, preferably on a municipal level, in decentralized combustion systems. Therefore, a municipality with a high percentage of area planted with corn is selected as a study area and this is Sto. Tomas, Pangasinan.

This study focuses on using the generated agricultural land cover map to determine the available energy potential of corn cobs produced in the study area and analyze whether it is enough to meet the municipality's demand for energy. The agricultural land cover map was generated from aerial images and point clouds acquired through light detection and ranging (LiDAR). Light detection and ranging is a remote sensing technology that collects 3-dimensional point clouds of the Earth's surface. This technology is being used for a wide range of applications including high-resolution topographic mapping and 3-dimensional surface modeling as well as infrastructure and biomass studies (USGS, 2015). Following the methodology used by Alberto et al. (2016), the detailed agricultural land cover map was classified using support vector machine (SVM), a powerful new generation learning algorithm which have been applied successfully to a range of remote sensing classification applications (Huang et al., 2002).

There are several factors that need to be considered in determining the available energy potential of a crop residue. According to Voinvontas et al. (2001), the available energy potential of the residue is a function of the area planted with the crop, residue yield, area of the region under consideration, collection efficiency, availability and the lower heating value of the residue. In this study, the area planted with corn in Sto. Tomas was acquired using the generated agricultural land cover map while the other values needed were acquired from field work activity and other literatures.

II. Methodology

A. Fieldwork

A total of 5 corn farmers from 2 barangays were visited for interview and data gathering. Data such as crop yield per farmer, area planted, address of farm, and number of times they plant corn per year were gathered. This was done to estimate how much corn cobs are available that may be used for energy production.

B. Resource Assessment

The agricultural land cover map of the study area was generated using remote sensing techniques and was derived from LiDAR data and aerial images of the municipality. From the LiDAR point clouds, several image layers that are important in the land cover classification were created. There

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are also image layers that were created from the aerial image of the study area. In total, there are six (6) image layers used in the classification of the land cover map. These are the normalized digital surface model, intensity, number of returns, red-green-blue, hue-saturation-value and the green-red vegetation index (Figure 1). The following softwares were used in the generation of the map: LasTOOLS, ENVI, eCognition and ArcMap. The generated agricultural land cover map was used to determine the corn plantation area.Title must be in 24 pt Regular font.

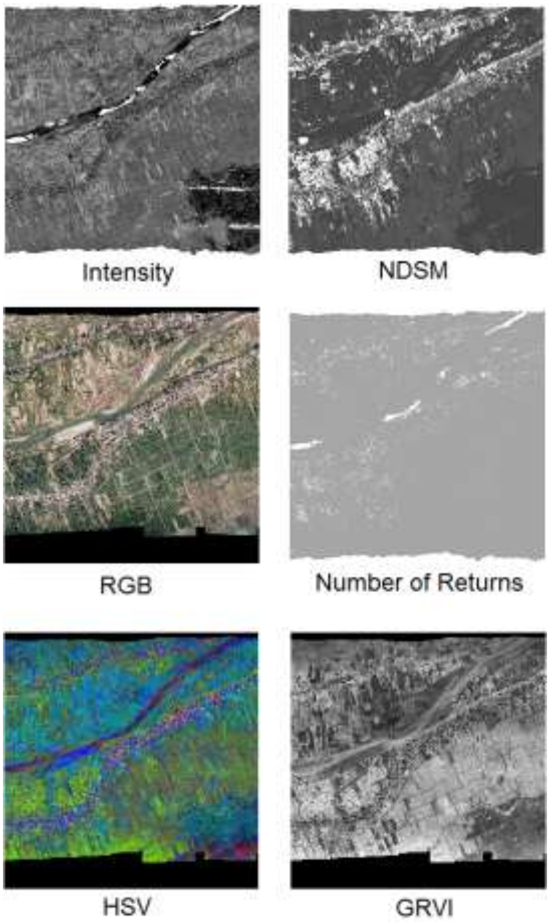

Fig. 1. Image layers used in the classification of the map.

C. Computation of Energy Contents

Voivontas, et al (2001) provided equations for the computation of the theoretical potential (B_n), which is the total production of residues in a region, and the available potential (B_{av}), which is the energy content of B_n. Equation [1] shows the formula for B_n while Equation [2] for B_{av}.

$$B_n = \sum_n A_n Y_n \qquad (1)$$

Where:

A_n = cultivated area for crop *n* (ha)

B_n = biomass theoretical potential for crop *n* (Mg /year)

Y_n = residue yield for crop *n* (Mg/km^2/year)

$$B_{av} = \frac{f_g \sum_n B_n a_n LHV_n}{A_r} \qquad (2)$$

Where:

a_n = biomass available for energy production from crop *n* (%)

A_r = area of the region under consideration (km^2)

B_n = biomass theoretical potential for crop *n* (Mg of residue/year)

B_{av} = biomass available potential (MJ/km^2/year)

F_g = efficiency of the biomass collection procedure (%)

LHV_n = lower heating value of the residue from crop *n* (MJ/kg)

In this study, values of 0.8 for F_g that was reported by Samson and Mendoza (2006) and 12.6 MJ/kg for LHV of corn cobs given by the Department of Energy (DOE) were used.

III. Results and Discussion

It was learned during the fieldwork that corn residues are just dumped and left to decompose in the periphery of the field after threshing. More often than not, the locals immediately gather the residues from the pile of corn cobs to be used as fuel for cooking and no residues were often left on the field. In this study, unsure whether the locals are willing to look for other alternative of firewood, an analysis was made on the energy content at different values of availability of corn cobs.

Through the SVM algorithm that was ran in eCognition software, the agricultural land cover map of Santo Tomas (Figure 2) was generated. Using this map, the area planted with corn in the municipality was geospatially computed with the value of 2.21 km^2. Using this computed area and assuming 100% availability of corn cobs, the B_n and B_{av} of the corn cobs in the municipality was obtained through Equations (1) and (2) which are 351.39 Mg and 3,541,997.63 MJ, respectively. The latter value will be the amount of energy that the corn cob can provide per year, since corn is only planted once annually.

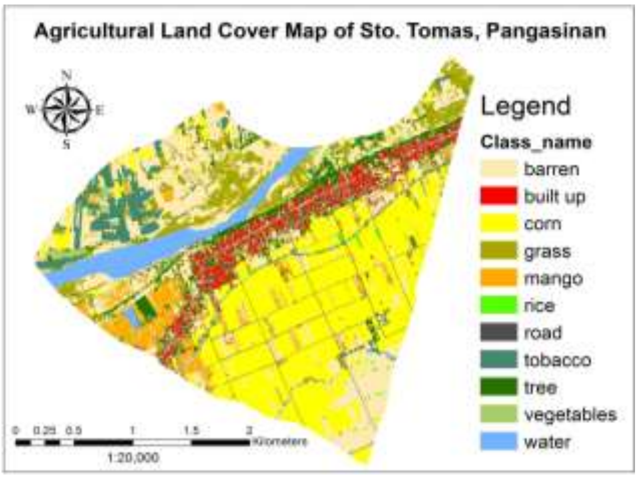

Fig. 2. The detailed agricultural land cover map of Sto. Tomas, Pangasinan.

Table I shows the total energy consumption of the municipality. The total energy content of corn cobs fall short to the municipality's yearly average consumption of 9,630,987.7 MJ. The corn cobs can only provide energy to the whole town for only 4 months and 12 days. An additional of approximately 604 Mg of corn cobs is needed to provide power for the remaining days of the year. However, it is not advisable to gather corn cobs from other municipalities because long distance travel of corn cobs is cost intensive and not meaningful (Brunner et al, 2011). An analysis comparing

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the computed energy content of corn cobs to each type of connections/users was carried out instead.

TABLE I. Number of connections by type of users and average consumption of Santo Tomas, Pangasinan (Pangasinan Electric Cooperative, 2012).

Type of Connection	Number	Average Consumption (MJ/Year)	Total Consumption	
			(MJ/Year)	%
Domestic	2,138	3,332.88	7,125,697.44	73.99
Industrial	2	30,504.38	61,008.77	0.63
Commercial	139	6,265.30	870,876.14	9.04
Public Buildings	19	28,476.58	541,832.54	5.62
Streetlights (Public)	384	2,638.22	1,013,078.02	10.52
Rice Mill	2	3,589.06	7,178.11	0.07
Welding Shop	3	3,772.22	11,316.67	0.12
TOTAL	**2,687**	**78,578.64**	**9,630,987.7**	**100**

Shown in Figure 3 is the yearly average consumption of each type of users with comparison to the total energy content of the corn cobs within the municipality. The computed energy content of cobs is still short to the total household's yearly consumption of 7,125,697.44 MJ. However, it is more than enough to power the rest of the users combined, with a total consumption of 2,505,290.25 MJ per year. This is, of course, under the assumption that 100% of the corn cobs are readily available. As mentioned earlier in this paper, most locals in the town use the corn cobs as fuel for cooking. This means 100% availability of corn cobs is theoretically impossible. Also shown in Figure 3 is the amount of energy that the corn cobs can produce at different percentages of availability.

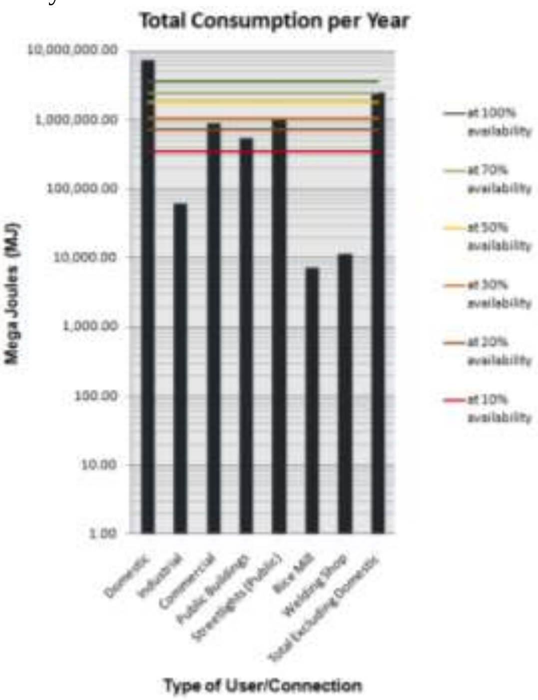

Fig. 3. The projected amount of energy content of corn cobs at different percentages of availability compared to the annual consumption of each type of connections.

It was already stated that at 100% availability of corn cobs, the energy content is not enough for all the households to be energized but is enough for the other users. The rest of the connections combined can be powered by the corn cobs at about 71-72% availability. Thirty (30) percent availability of corn cobs is enough to power either one of the rest of the users excluding the domestic but at 20% availability, it will not be enough to power the commercial buildings and streetlights. At the very least, all the industrial buildings, rice mills and welding shops combined can still be powered by the corn cobs at only 10% availability.

It would be better for the corn cobs to be used to provide energy for domestic houses so that there would be more beneficiaries. The domestic houses, although not all, will have more units that can be powered by the corn cobs (Table II). Additionally, people will be directly benefited if the renewable energy is used to power their homes. However, at corn cobs availability of 30% below, more units of street lights can be energized.

TABLE II. Number of units for each type of user that can be powered by corn cobs based on the average yearly consumption per year on different percentages of availability of residue.

Type of Connection	Number of units energized at different percentages of corn cobs availability (%)									
	100	90	80	70	60	50	40	30	20	10
Domestic	1063	956	850	744	638	531	425	319	213	106
Industrial	2	2	2	2	2	2	2	2	2	2
Commercial	139	139	139	139	139	139	139	139	113	57
Public Bldgs.	19	19	19	19	19	19	19	19	19	12
Street Lights	384	384	384	384	384	384	384	384	269	134
Rice Mills	2	2	2	2	2	2	2	2	2	2
Welding Shops	3	3	3	3	3	3	3	3	3	3

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