GIS-BASED METHODOLOGY ON TECHNO-ECONOMIC POTENTIAL ASSESSMENT OF SUGARCANE RESIDUES IN MEDELLIN, CEBU, PHILIPPINES

Wenyville Galang (1,2), Ian Dominic Tabañag (3), Michael Loretero (4)

1 Engineering Graduate Program, School of Engineering, University of San Carlos,
Cebu City 6000, Philippines
2 College of Engineering and Computer Studies, Holy Name University,
Tagbilaran City 6300, Philippines
3 Department of Chemical Engineering, University of San Carlos,
Cebu City 6000, Philippines
4 Department of Mechanical and Manufacturing Engineering, University of San Carlos,
Cebu City 6000, Philippines
Email: naborgalang@gmail.com; iftabanag@usc.edu.ph;
meloretero@usc.edu.ph

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ABSTRACT: The act of burning traditional biomass results in indoor air pollution, which has negative effects on health such as respiratory, pulmonary, and cardiovascular diseases. The practice also contributes to ambient air pollution and climate change through the emission of carbon dioxide (CO2) and non-CO2 pollutants formed by the incomplete combustion of biomass. To help reduce air pollution coupled with its effect on climate change specifically the agricultural residues left on fields and burned, a Geographic Information System (GIS) supported assessment was developed to determine the techno-economic potentials of utilizing agricultural residues in Medellin, Cebu. The methodology was based on GIS analysis of agricultural, economic and climatic data employed in GIS spatial analysis platform. Data about land use, transportation facilities, urban cartography, regional territorial planning, terrain digital model, and climatic types have been stored in the GIS to define potential areas for gathering the residues coming from sugarcanes and to assess available for energy cultivation. The sugarcane is an abundant agricultural crop in the locality and its residue is the major feedstock available for bioenergy. The results reveal a meaningful technical and economic potential concentration in the locality feasible for biomass power plant for electricity generation. The assessment has shown a strong competitiveness of sugarcane residues for bioenergy when the collection system is implemented in an efficient way. An outcome of the study was to show the opportunities originating from issue of addressing energy security by utilizing indigenous energy resources.

1. INTRODUCTION

Biomass is an abundant renewable energy source for agriculture led countries. In the Philippines, at least 24% of its land area is used for agricultural activities and 90% of which dedicated to growing crops. The high abundance of biomass, its fast regeneration and the general easy accessibility are factors in favour of it being used as a renewable energy source. Principal targets for the biomass generation are forests and agricultural areas. Biomass can be used for direct heating in industrial or domestic applications, in the production of steam for electricity generation or for production of gaseous or liquid fuels (Voivontas D. et.al., 2001).

Biomass resources can be grouped into wood residues, generated from wood products industries; agricultural residues, generated by crops, agro-industries and animal farms; energy crops, examples are crops and trees dedicated to energy production; and municipal solid waste (Easterly JL, Burnham M., 1996).

Biomass for energy use has an important contribution to meeting global energy demand and its role in the modern energy supply mix is expected to expand significantly. Bioenergy, as energy derived from biomass, addresses energy access challenges. It provide opportunities for social and economic development in agricultural communities, contribute to local energy security, improve the management of resources and wastes, and provide environmental benefits such as greenhouse gas (GHG) savings. In spite of its flexibility as an energy resource, biomass share in national energy balances is rather low.

The Philippines' electricity consumption grew by an annual average growth rate of 4.49 percent despite the country's increased exposure to global risks and uncertainties including the detrimental impacts of natural calamities such as major typhoons, earthquake and drought (Department of Energy, 2016). Moreover, the robust growth of the services, industrial and agriculture sectors attributed to the impressive performance of the economy have driven the increase in electricity consumption. The country's total installed capacity grew by an annual average growth rate of 3.81 percent from year 2011 to 2015. The increasing installed capacity is a good economic reference that the power sector is improving and adapting to the growing demand of the country. This huge growth is associated to the increased installation of large coal-fired power plants.

The Philippines ended 2017 with a total installed capacity of 22,728 megawatts (MW), of which coal has remained the dominant energy source with a share of 35.4%, according to the Department of Energy (DoE). Coal-fired power plants had a total installed capacity of 8,049 MW. Renewable energy (RE) sources followed closely at 7,079 MW or 31.1% of the total, although taken individually only hydroelectric power plants posted a double-digit share of the total at 16% or 3,627 MW. Oil-based energy sources made up 18.3% of dependable capacity at 4,153 MW. Natural gas had a share of 15.2% or 3,447 MW as of end-2017. The latest DoE data of 2016 indicated coal power plants' share to have expanded from 34.6% in 2016.

Coal generation increased in the past years and became the most dominant and most utilized source in the generation mix. This is because coal plants provide low-cost generation and a stable operation. Currently, there are various sources of renewable energy in the country and natural gas and coal are still the most utilized indigenous fossil fuel source.

In the Philippines, biomass as an energy resource share in national energy balances is still low. In spite of its small share it provides a meaningful contribution to the power sector. As of December 2016, there were 16 existing biomass-fueled power plants in the Philippines, of which 9 were in Luzon, 6 in the Visayas, and 1 in Mindanao. Four more had been approved but were not yet operational. Of these plants, nine run on bagasse that refers to the residue from sugarcane processing, four on ricehusks, and three uses a landfill gas recovery system (Department of Energy, 2016). They collectively provide 233 MW of installed capacity, or alternatively 157 MW of dependable capacity which is 0.8% of the country's dependable capacity.

As part of its commitment to expanding the renewable energy sector and reducing carbon emissions, the DOE has sought to grow biomass for use in power generation. This is in view of the fact that burning of traditional biomass results in indoor air pollution, which has negative effects on health such as respiratory, pulmonary, and cardiovascular diseases. The practice also contributes to ambient air pollution and climate change through the emission of carbon dioxide (CO_2) and non-CO_2 pollutants formed by the incomplete combustion of biomass.

The efficient utilization of biomass as alternative renewable energy source provides counter measure for the country's energy challenges that highlights the high cost of electricity and the importance of achieving a more affordable and adequate supply of electricity to improve the competitiveness of the country's economy. Biomass assessment provides information on how to effectively utilize such renewable energy source.

The main aim of this study is to develop a method in Geographic Information System (GIS) environment in order to determine the biomass potential. GIS is a computerized platform for geographic data visualization, processing, and analysis. A GIS has been used in many bioenergy studies. In these analyses, road maps, soil maps, and land use maps are linked with forest productivity and economic models. At a national scale, GIS have been used to assess the biomass sources availability and to examine the best locations, given economic and environmental conditions, for putting up bioenergy facilities in some countries.

In GIS, a geo-spatial data is stored in layers that represent georeferenced measures of a geographical variable (Gemeli, A.et.al., 2011). GIS-based approaches have been used to analyze energy potentials from various renewable energy sources (Natarajan K. et.al., 2016). The use of free and open source software like Quantum GIS provides flexibility and ease of use to edit and combine geo-spatial datasets in order to derive estimations on spatial distribution of available biomass such as agricultural residues and to determine optimization model input parameters.

There are several assessment techniques and approaches on the assessment of biomass as a renewable energy resource carried out in other countries. The different approaches include resource availability (Papilo P. et.al., 2017), bioenergy potential estimation (Becalli, M. et.al., 2009.), using GIS application and land use/ land cover maps (Singh, J. et. al., 2008, Hohn, J.et.al., 2014, Panichelli, et.al., 2008), and approach for defining bioenergy facilities along with its cost-benefit analysis (Hohn, J.et.al., 2014, Panichelli, et.al., 2008) and among others.

In the Philippine setting, there are several studies that used GIS for bioenergy study. The estimation of rice hull energy potential in Camarines Sur Philippines used Landsat-derived agricultural maps and mathematical model employed in a GIS platform (Sevilla, K. et.al. 2015). The method was adapted to generate an agricultural land cover map and extract areas allocated for rice production. It also performed comparison of MODIS-based rice extent map and Landsat-based rice classification map in determining biomass energy potential of rice hull in Nueva Ecija (Sevilla, K., 2016). The statistical and spatial field validated parameters were analyzed and processed using GIS. At a finer spatial resolution, a GIS-based study was used to improve the accuracy of values, spatial images with higher resolution like LiDAR technology. The utilization of LiDAR-derived Agricultural Map provides a more detailed data that facilitate a barangay-level of assessing the biomass resources such as sugarcane residues. Its detailed GIS-based calculation facilitates easier and faster way of deriving parameters needed for Biomass Resource Assessment ([14] Cadalin, M.et. al., 2015, Novero , A. et. al., 2019).

The above mentioned assessments focus on theoretical potential of biomass resources such as agriculture residues. Specifically, it determines the maximum number of total land biomass that is theoretically available for bioenergy production with basic biophysical limits. The theoretical potential is usually expressed in Joules primary energy, which is the energy contained in the biomass raw material, and has not been processed. Primary energy is converted into secondary energy, such as electricity, liquid fuels, and gaseous fuels. In the case of crops and forest biomass, theoretical potential describes the maximum productivity under theoretical optimal management by considering constraints such as soil conditions, temperature, solar radiation, and precipitation (Papilo P. et.al., 2017).

Technical potential is part of the theoretical potential that is available under the techno-structural condition with current available technology such as harvesting techniques, infrastructure and accessibility, and processing techniques. The technical potential also considers the spatial conditions related to land use including ecological aspects and constraints due to the possibility of non-technical use. While the economic potential is part of the technical potential that meets the criteria of economical profits under certain conditions.

However, the study that focuses on technical potential of biomass resources is still rather lacking. This accounts to the limited knowledge on the techno-economic potential of agricultural residues for bioenergy purposes. Lack of availability of data, undeveloped knowledge and technology utilization of biomass energy, cause portions of the utilization of biomass energy for the effort to fulfill the energy needs of society and increase the portion of renewable energy in the national mixed energy is still quite low.

2. METHODOLOGY

The Philippines is an agriculture led country that provides a high opportunity to explore biomass for energy purpose. In order to assess the potential from agricultural residues, it is necessary to account for areas where the biomass residue is produced. This is accomplished through GIS processing of Medellin, Cebu agricultural land cover map. This Agricultural Land-cover Map, a classified map using Object-based Image Analysis or OBIA was obtained from Philippine Agricultural Resources Mapping or PARMAP of Department of Science and Technology PHIL-LiDAR2 DREAM Project using LiDAR remote sensing technology. Figure 1 shows the map based on LiDAR datasets obtained from July 23, 2014 to July 24, 2014 which provides high spatial resolution agricultural resource map cover. The high accuracy of airborne LiDAR technology for land cover classification and object recognition can be attributed to the predominant height features derived from the LIDAR point cloud and capability of acquiring 3D topography data.

Remotely sensed data provide the synoptic view of the surface area of interest, thereby capturing the spatial variability in attributes of interest. The spatial coverage of large area biomass estimates that are constrained by the limited spatial extent of forest inventories may be expanded through the use of remotely sensed data. Biomass assessment derived from forest inventory data may have some spatial, attributional, and temporal gaps. Remotely sensed data was used to fill these gaps, thereby leading to estimates closer to the actual value.

This methodology was applied in Medellin, a 2nd class municipality in the province of Cebu, Philippines. The municipality of Medellin is one of the nine municipalities comprising the 4th congressional district of Cebu province. It is approximately 120 kilometres (75 mi) north from Cebu city via Barangay Curva, or 113 kilometres (70 mi) via Barangay Luy-a. Medellin is bordered on the north by the town of Daanbantayan, to the west by the Tañon strait, on the east by the Camotes sea, on the southwest by the town of San Remigio and the southeast by the city of Bogo. The municipality is part of the Bogo-Medellin mill district in the province of Cebu along with Bogo, Borbon, San Remegio, Daanbantayan and Tabogon. For crop year 2013-14, the mill district has a total sugarcane area of 7,900 hectares with a total sugar production of 27,297 tons which constituted 1.12% of the national production.

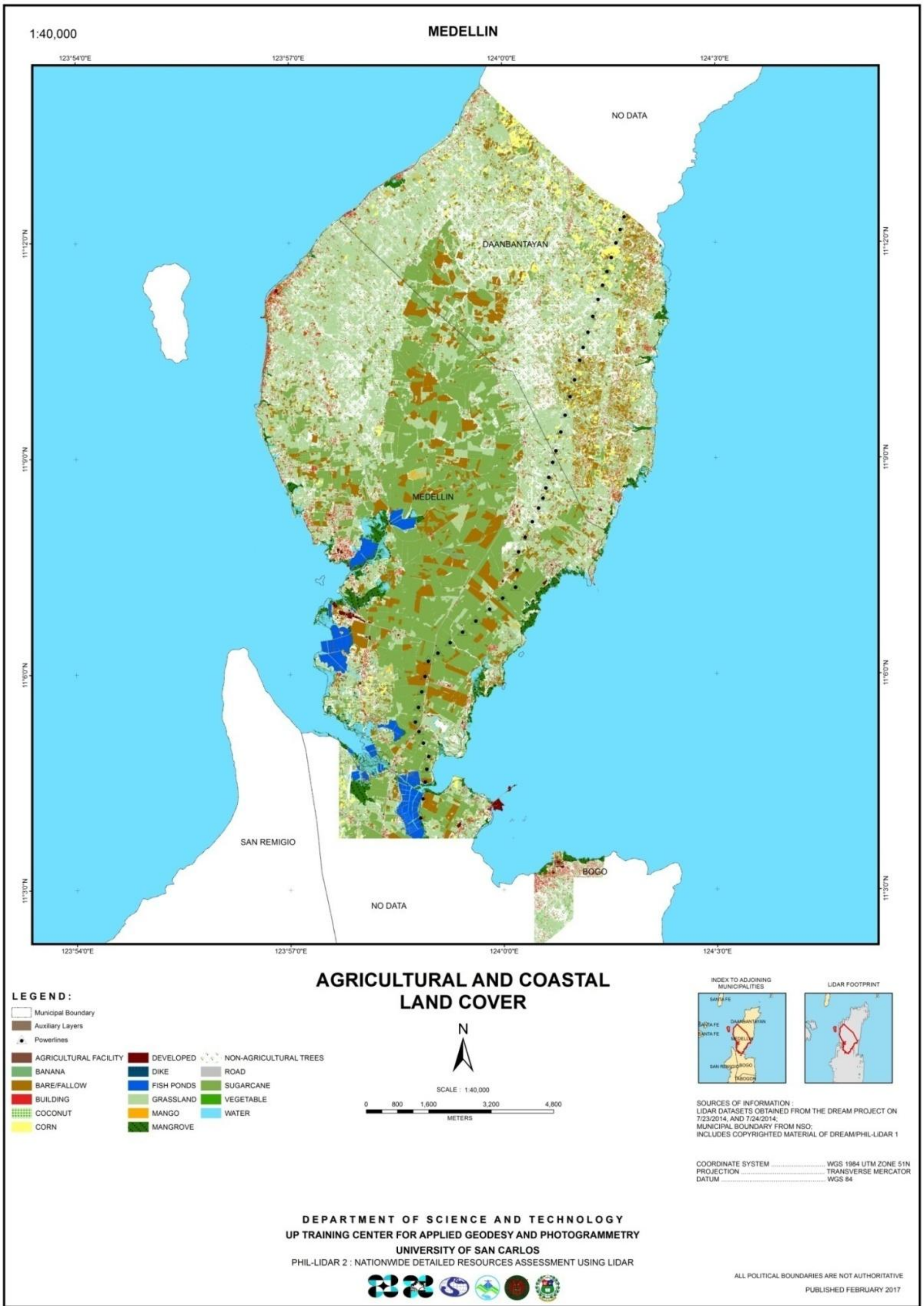

Figure 1. Land Cover of Medellin, Cebu

The municipality of Medellin in the province of Cebu is composed of 19 barangays or villages, with a total land area of 73.19 km2. Based on the data from LiDAR capture as of 2014, eighteen of those areas are feedstock sources of sugarcane. These areas form part of the Bogo-Medellin mill district. Extracted data attributes from the Agricultural Land-Cover Map of Medellin Cebu served as the major data input in the calculation of land area and cultivated area for sugarcane. The theoretical potential is a straight forward calculation of the sugarcane residues in GJ. It is computed as the product of the yield of main produce in t/ha, the residue-to-product ratio of harvest residues, the production area in ha., the moisture content as a percentage of the fresh matter and higher heating value of the residues in GJ/t.

Table 1: Overview of the Factors Required to Assess Theoretical Potential (THP)

Residue Type	RPR	HHV_{dry}	MC%
Harvest Residues (sugarcane tops, green and dry leaves)	0.15	16.7	67
Process Residues (bagasse)	0.29	19.0	50

The amount of residues produced, and thus potentially available for bioenergy production, is calculated using the residue-to-product ratio. The significant differences between RPR's used in different studies however recent studies generally assume average ratios (Macedo, I.C. et. al. 2001). In reality the residue-to-product ratio is not constant. It depends on the yield on the one side but also on stresses the crop experiences during growth, for instance caused by draught.

The higher heating value of the harvesting residues depends mainly on the ash content of the biomass (Jenkins, B.M. et.al., 1996).This in turn depends on the composition of the biomass, the more woody material the mixture contains the lower the ash content and the higher the HHV. The HHV of the residues was calculated based on the ECN Phyllis database for biomass and waste (Energy Research Centre of the Netherlands 2011) and the biomass feedstock composition and property database (US department of energy 2004). Both data bases contain original data obtained from analysis of residue samples and thus provide a solid reference. The averages of the data from both databases were used to calculate the overall average.

The moisture content of the harvest residues depends on the time of residue harvest. In this study, the moisture content of the residues was regarded as a constant factor as measured when the crop has reached maturity. Table 1 provide an overview of the values used in relevant literature for sugar cane tops and leaves and sugar cane bagasse respectively, and the averages thereof that are used throughout this study (Hassuani, S.J et. al., 2005 and Energy Research Centre of the Netherlands 2011)

The use of a land cover map specifically the ones obtained from remote sensing technology such as the LiDAR data provides the possibility to highlight the potential areas where the agricultural residues coming from and their abundance as well as distribution. The LIDAR-derived agricultural resource map has very detailed crop information and high spatial resolution to enable derivation of other resource maps at different scales. A municipality-scale LIDAR-derived resource map can be subdivided into barangay-scale resource maps without sacrificing the resolution of the resulting submap as shown in Figure 2.

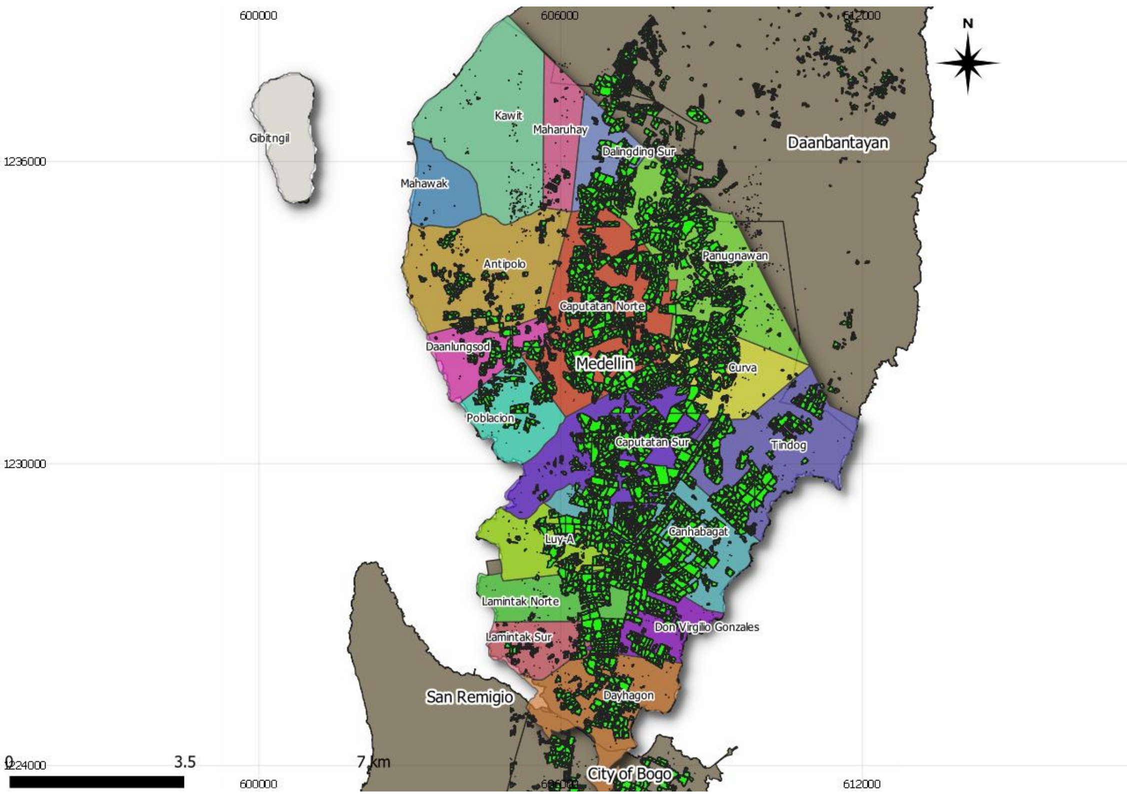

Figure 2. Medellin, Cebu sugarcane abundance and distribution

The municipality of Medellin is abundant in sugarcane crops. The proper maintenance of crops may provide a large amount of residual biomass. This study considers the climatic requirement of growing sugarcane given the climatic condition in the locality.

Sugarcane is a tall perennial grass of the genus Saccharum, native to Southeast Asia and parts of the South Pacific. It can grow in warm temperate or tropical climates. The internodes of the plant stalk are rich in the sugar sucrose, and the plants can grow to a height of two to six meters in height. Principal climatic components that control sugarcane growth, yield and quality are temperature, light and moisture availability. The plant thrives best in tropical hot sunny areas.

The ideal climate for production of maximum sugar from sugarcane is characterized as a long, warm growing season with a high incidence of solar radiation and adequate moisture or rainfall. Though sugarcane can be cultivated in temperate zones, productivity is much higher in tropical climates. A long, sunny, and hot with 32 °C to 38 ° of temperature on growing season with moderate to high levels of rainfall of about 1100 and 1500 mm total, combined with a dry and cooler harvest season is ideal as summarized in Figure 3.

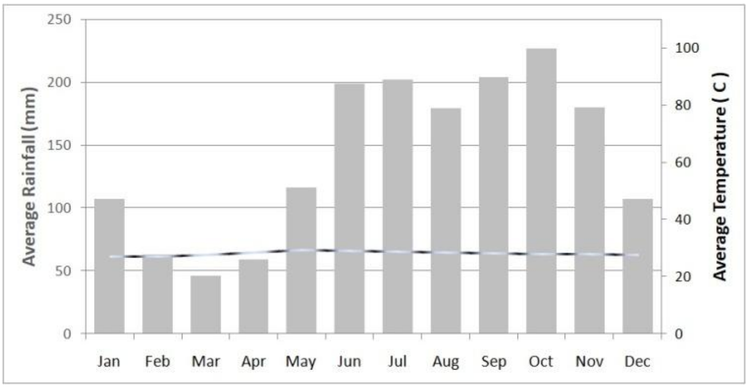

Figure 3. Medellin, Cebu Climate Graph

The next step was to assess the amount and distribution of biomass residues with economic potential. By means of slope map, road network map and climate type are parameters to assess easy access, good technical potential with respect to the amount and distribution of biomass residues with economic potential. Resulting map in Figure 4 and 5 were obtained using GIS capabilities. The methodology adopted to assess the quantity and the distribution of the agricultural residues is based on the spatial analysis features of a GIS. The GIS used was with database that contains information about land cover, land use, administrative boundaries, road network, digital terrain model and climatic data.

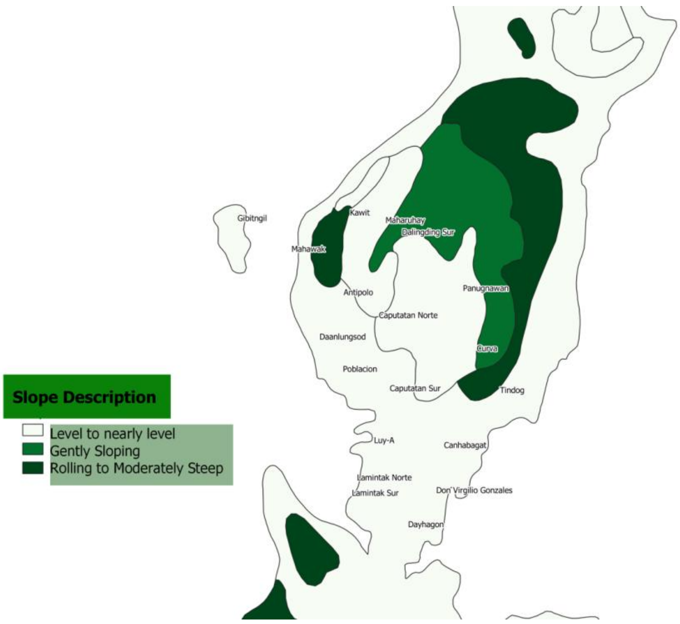

Figure 4. Terrains in Medellin possible for sugarcane cultivation

The possibility of cultivating sugarcane is determined by land terrain. In Medellin, all the areas with a slope level to nearly level were considered as potential areas for sugarcane cultivation. These areas are identified in which sugarcane is abundantly growing and present. These represent the main economic sectors from which it is possible to obtain process and harvest residues for energy uses.

In the assessment of economic potential, the main goal was to assess the cost of biomass production. The cost of biomass results from the sum of the costs of harvesting operation and residue gathering. Transportation cost turned out to be the most relevant factor. Table 2 showed the overview of post harvest cost from Sugar Regulatory Administration (SRA) provided by Mill District Development Councils (MDDC) and Extension Field data.

Table 2: Overview of Post Harvest Cost for Bogo-Medellin Mill District, Pesos per Hectare, CY 2012-2013

		Small	Medium	Large
Expenditures	Farm Size	Less 10 ha	Between 25-50 ha	50.01 ha and above
Cutting and Loading P175/TC		7000	9625	10500
Net Hauling Cost				
Hauling Cost P200/TC		8000	11000	12000
Drivers allowance per trip P400/trip		800	1100	1200
No of trips of 20 ton capacity truck		2	2.75	3

3. RESULTS AND DISCUSSION

Theoretical potential is the upper limited of bioenergy production from residues, limited by fundamental physical and biological constraints and the current production of agricultural crops. It is computed as the product of the yield of main produce in t/ha, residue-to-product ratio of harvest residues, production area in ha., moisture content and higher heating value of the residues in GJ/t.

The Biomass Theoretical Potential of Medellin, Cebu sums up to 6823.29 GJ of harvest residues and 22740.18 GJ of process residues coming from sugarcane in consideration of its cultivated areas and production yield. The villages of Caputatan Norte, Caputatan Sur and Canhabagat were the top three largest cultivated areas for sugarcane with 429.0 ha, 331.61 ha and 297.22 ha, respectively. The biomass potential of the municipality from sugarcane residues can at least produce from 1895.36 to 6316.72 megawatt-hour (MWh) of electricity. One MWh is equivalent to one megawatt of constant power expended for one hour of time.

Extracted data attributes from the Agricultural Land-Cover Map of Medellin served as the major data input in the calculation of cultivated area for sugarcane. The map contains various agricultural features and sugarcane has been segregated with the use of GIS features to calculate the sugarcane cultivated areas. In addition, this study used 45.46 TC/Ha – tons cane per hectare, as a measure of farm productivity provided by SRA SUGARCANE-ROADMAP-2020 data.

Table 3: Attribute Table of Medellin Farm Cultivated Area, Productivity and Theoretical Potential

Name of Barangay	Cultivated Area in ha (hectares)	Farm Productivity in T (tons)	Harvest Residues THP (GJ)	Process Residues THP (GJ)
Antipolo	68.84	3129	196.630263	655.3152782
Canhabagat	297.22	13512	848.9605866	2829.355127
Caputatan Norte	429	19502	1225.368722	4083.821242
Caputatan Sur	331.61	15075	947.190028	3156.727185
Curva	110.46	5022	315.5110235	1051.512574
Daanlungsod	58.29	2650	166.495904	554.8856415
Dalingding Sur	83.309	3787	237.9586081	793.051431
Dayhagon	128.087	5823	365.8596819	1219.310982

Don Virgilio Gonzales	109.856	4994	313.7857957	1045.762859
Kawit	1.147	52	3.276218938	10.91874817
Lamintak Norte	82.309	3742	235.1022708	783.5320341
Lamintak Sur	42.61	1937	121.7085344	405.6214992
Luy-A	103.77	4717	296.4021266	987.8278096
Maharuhay	7.3329	333	20.94523614	69.80478505
Mahawak	0.084	4	0.239932337	0.799629334
Panugnawan	286.73719	13035	819.0181449	2729.565099
Poblacion	49.6789	2258	141.8996975	472.9131634
Tindog	198.4853	9023	566.9409754	1889.460337
Gibitngil	0	0	0	0

The assessment of biomass production cost provides valuation on the amount and distribution of biomass residues with economic potential. The cost of biomass involves cost in harvesting operations, gathering and transportations. The road network facilities provide efficient means to linked residue collection center to possible energy plant. In addition, the selection of potentially productive areas was on the basis of nearly level slope, easy accessibility and slightly affected or free from erosion.

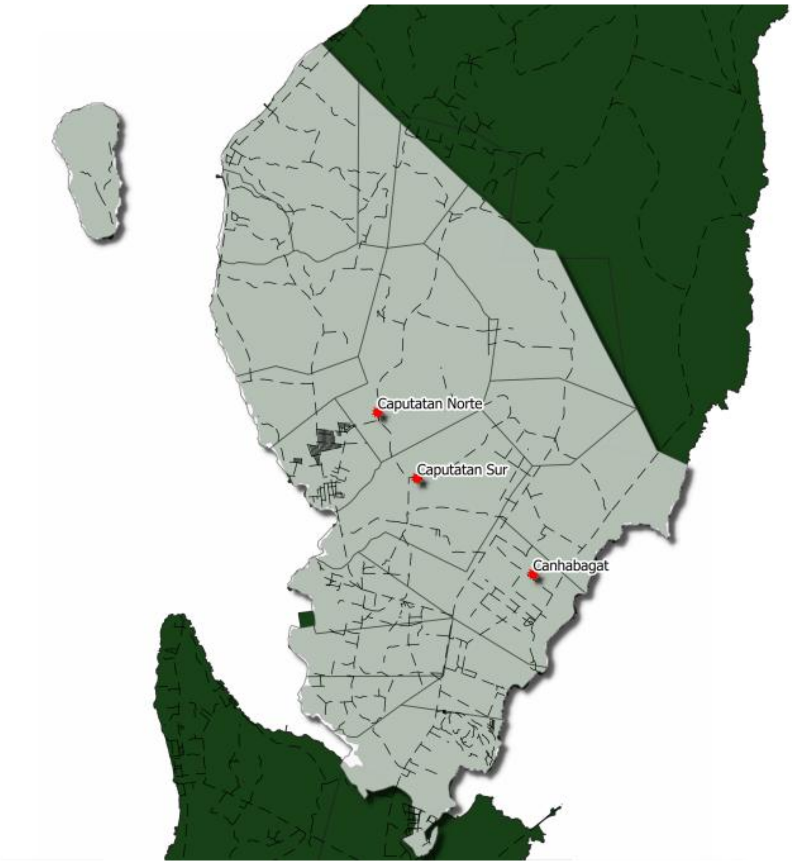

Figure 5. Biomass collection center in Medellin

It is also essential to define the manner and the cost of biomass transport to the collection centers. Cultivation type, harvesting techniques, transportation means and distance from collection centers are factors to be considered in identifying the cost. Identification of unit transportation cost lead in creation of economic supply curve for sugarcane residues in the locality of Medellin, Cebu.

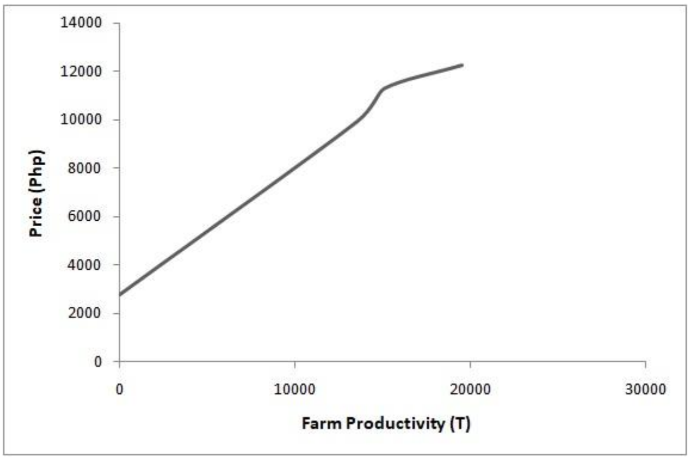

Figure 6. Supply Curve of Sugarcane Residues in Medellin

4. CONCLUSION

The use of GIS-based methodology provides an overview of the energy potential of biomass coming from agricultural waste in Medellin, Cebu. The approach considered the territorial components that influence the bio-energetic generation and its economical convenience, including proximity to roads, structure and elevation of terrain, density of resources and other factors.

The promotion of biomass utilization particularly the residues which generally left in fields and burnt is an alternative to supply primary energy demand and electricity production. An action related to biomass exploitation includes centers that could be created near centers for gathering the residues to take advantage of sharing personnel and cost. Factor to consider also is to establish center located where there is a relevant potential. For a good techno economic potential a group of common network facilities such as collection center would allow the gathering and transportation of biomass residues from related districts in an efficient framework. The location and sizing of these centers would have to be linked to the agricultural and geographic characteristic of the locality, together with the existing infrastructure for the gathering of the residues.

Theoretical potential estimated showed that the sugarcane industry has the potential to generate power to the grid which can be harnessed through efficient biomass resource utilization and firm policy support by government in implementing the renewable energy law. Biomass power is included in the renewable energy targets under the 2011-2030 National Renewable Energy Plan (NREP 2011-2030) stating a target to achieve 276.7 MW of power for its Renewable Energy Targets short term goal for 2011-2030 is achievable given the effective and efficient residue collection for power generation..

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