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GIS-Based Estimation of Biomass Available and Energy Potential from Corn Residue in Bukidnon

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ABSTRACT

Biomass resources from forests and agriculture residues are underutilized and lost mostly in the provinces in Mindanao and other less developed areas in the country. This article focuses on the estimation of biomass available and energy potential of corn residue in Bukidnon. The study was carried out using survey questionnaires and government agriculture reports to investigate the potential biomass resources and the existing domestic and commercial uses of biomass in the province. Integration and analysis was done using ArcGIS platform and in mapping out geographic distribution and concentration of biomass resources. It is established that the annual biomass theoretical potential for Bukidnon is about 502,343.38 metric tonnes, which corresponds to an annual energy production potential of 2,252,016,879.08 MJ. Concentration of biomass theoretical potential is highest in District 2 and District 3 and consequently the energy potential of 144,220,522.03 kWH and 298,793,184.33 kWh, respectively. The outcomes of the present study indicate that for studies to develop site suitability analysis for power plant development including other leading agronomic crops may be considered.

Keywords: *ArcGIS, bio-energy, biomass mapping*

INTRODUCTION

The need for affordable, dependable and renewable alternative sources of energy is one of the frontline challenges in the 21st century. Improvement of local energy resources will result to lesser reliance on imported oil which is the ultimate aim of any related efforts. The use of crop residues as biofuels is of increasing interest in the Philippines as fossil fuel prices continue to rise. Crop residues are easy to collect and interesting source of biomass feedstock for energy generation. However, the current utilization rate of these potential sources of primary biomass energy mix in the Philippines such as wood-based waste, animal wastes, and agricultural residues including those from cane, coconut and rice is still very minimal. Moreover, other agricultural biomass such as corn, which is one of the major crops in the country that is produced in huge volumes, is not considered. According to Bioenergy Consult (2016), it is estimated that 0.96 million tonnes of corn cobs are produced yearly with burning as the main energy application of the crop, and is widely practiced by small farmers to supplement fuelwood for cooking.

Bukidnon is the leading corn producing province of the country according to IPFAD-CIMMYT Project Report in 2002. In terms of physical distribution of agricultural areas within the province, corn lands are second only to sugarcane followed by pineapple and irrigated rice. Corn still remains as the most popular agricultural commodity produced by farmers within the province in terms of crop areas harvested as majority of the agricultural lands is devoted to its production. In 2012, white and yellow corn production volume is highest in Bukidnon among other provinces in Northern Mindanao. Yellow corn production is significantly higher than white corn because Bukidnon, which contributes 70% to the regional production, emphasizes the yellow corn variety mostly for animal feed (Calalang, G. M., Bock, L., & Colinet, G., 2015).

While report on corn production and devoted land area is high compared to other crops (except sugarcane), therefore assumed to have high production of biomass residue, availability for energy production is yet unknown. Congruently, energy potential of corn biomass residue has not been explored. Saladaga et al for example, conducted a site suitability analysis for biomass power plant development with rice residue as the biomass resource. Other studies on biomass energy potential focused on forest residues and animal wastes. This heightens the need for a study on biomass availability and energy potential for corn residue.

Assessment of biomass residue available and potential for energy production is a relevant requisite in site suitability analysis for investing in biomass power plant development. Wakeyama (2011) proposes that a systematic and accurate estimation of biomass available potential is vital in the process. Estimation of biomass potential can be evaluated by investigating the theoretical potential that shows residue of the area yearly, and the available potential that provides the actual amount of energy that is contained therein (Sevilla et al., 2015). A method for assessing biomass potential designed for local-specific area used a decision support system using GIS or Geographic Information System (Voivontas et al., 2000). GIS is used for quantifying the biomass residue potential (including spatial distribution and concentration) of biomass residue in different municipalities. It is in this context that this study is conducted in order to examine the volume of corn biomass residue available and the available potential for conversion into electricity. This study would be the first in the province that investigates the biomass potential of corn residue for energy production. Future studies on bio-energy site suitability analysis using agricultural biomass can build on the output of this research.

METHODOLOGY

The province of Bukidnon in Northern Mindanao (Region 10) is bounded by the provinces of Misamis Oriental, Agusan del Sur, Lanao del Norte, Cotabato, Davao, and Davao Oriental. It consists of 2 cities, 20 municipalities, and 464 barangays. It ranks the 3rd biggest province in the country in terms of land area of 10,498.59 km2 and with income classification as 1st Class. It holds a total population of 1,4515,226 (NSO 2015). The province is divided into four (4) legislative districts for expediency of governance. First District covers the municipalities of Baungon, Libona, Malitbog, Manolo Fortich, Sumilao and Talakag. Second district holds the City of Malaybalay and municipalities of Cabanglasan, Impasug-ong, Lantapan and San Fernando. Third District has Damulog, Dangcagan, Don Carlos, Kadingilan, Kibawe, Kitaotao, Maramag and Quezon. Last, the 4th District covers Valencia City, Kalilangan and Pangantucan. The Bukidnon Corn Production Data C.Y. 2015 Report by the Provincial Agriculture Office was used in determining the total physical area planted with yellow and white corn in that year. The report recorded a total of 138,091 hectares in which 116, 707 (85%) hectares were planted with yellow corn and 21,384 (15%) hectares were planted to white corn.

The study covered series of progressive steps from collection of secondary data, survey interviews, consolidation and pre-processing of data, analysis using GIS platform, and generation of maps. A mathematical model is used in deriving the available biomass and energy potential of corn residue using GIS as the platform for analysis. GIS allows spatial representation of results through maps showing distribution and concentration of available and energy potential of the biomass residue. This study focused only on corn residue due to the availability of field data gathered from January to August 2016. Unavailability of highly accurate agricultural classification map also puts limitations on the analysis.

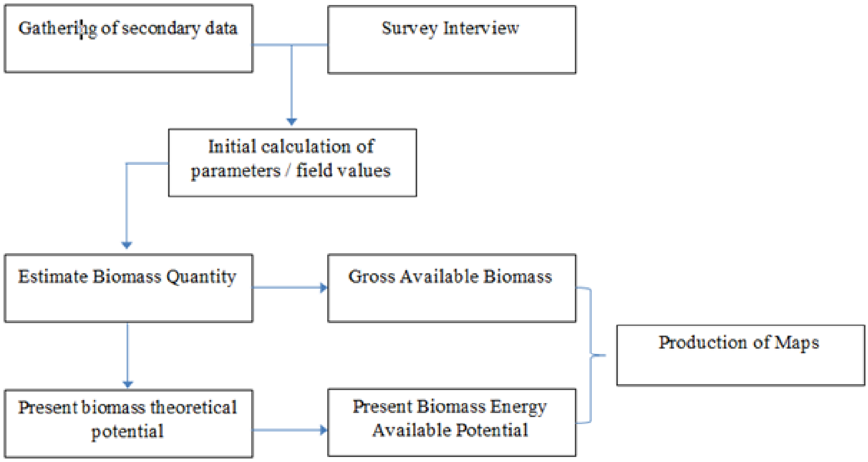

Figure 1. Research Framework

Agricultural map of the province should have been useful in the analysis and mapping of the corn production areas; however this was not available at the time of the study. Administrative boundary for municipal and city boundaries were sourced out from the Philippine GIS Data Clearing House. Road network was sourced from the Department Works and Highways. Figure 1 present the study framework for the estimation of biomass potential.

Interview provides more accurate information on the availability of biomass residue for energy production: quantity of biomass that farmers are willing to sell over the volume produced annually. Existing socio-cultural and economic uses and practices determine availability of residue. Interview results conducted in each municipality/city in the province were used in mapping available biomass resources.

Survey questionnaires were administered to around 220 randomly selected corn farmers. Small scale farmers usually sell corn grains keeping the cobs with them or leaving them where shelling took place. While large scale farmers directly sell harvested corn cob to milling companies. The latter hold large volume of cobs at their disposal. Respondents had given information on their annual corn and residue production, uses of residue, and volume of residue they are willing to give away for an amount. Secondary data was also obtained from the Office of the Provincial Agriculture of Bukidnon. In demarcating the administrative units of Bukidnon, the boundary data that was used in this study was from the Database of GADM or Global Administrative Areas.

According to Voivontas, et al. (2011) the available biomass potential is defined as "the energy content of the biomass that can be technically and economically harvested and used for energy purposes." A mathematical model for biomass resource computation was carried using ArcMap 10.2.2. This same method was carried out by the Biomass REMap Component under the Central Mindanao University Phil-LiDAR 2 Project. The formulas from Voivontas, et al. (2011) were used in the derivation of the biomass available residue and energy potential expressed in megajoules (MJ).

$$B_n = \sum A_n Y_n \qquad \text{Equation (1)}$$

$$B_v = \frac{f_g \sum B_n a_n LHV_n}{A_r} \qquad \text{Equation (2)}$$

Where:

A_n = cultivated area for crop n (ha)
Y_n = *crop yield * crop to residue conversion factor*
B_n = biomass theoretical potential for crop n (MT residue/yr)
f_g = efficiency of the biomass collection procedure (%)
B_n = biomass theoretical potential for crop n (MT residue/yr)
a_n = biomass available for energy production from crop n (%)
LHV_n = lower heating value of the residue from crop n (MJ/kg)
A_r = area of the region under consideration (ha)
B_v = biomass available potential (MJ/ha/yr)

Eq (1) quantifies the volume of corn residue available in the municipalities and cities. It estimates the quantities of corn residue (cob) generated annually. Eq (2) calculates the energy content potential biomass in Mega joules (MJ) per hectare per year; in light of farmers' other uses of residue at the farm level. Values for LHV (MJ/Kg) at 15% moisture content and crop to residue conversion factor were taken from Biomass Atlas 2000 assumption. Corn cob LHV is 12.6 MJ/Kg and with crop to residue conversion factor of 0.27 kg of corn cob per kg of corn. Both equations are used to generate the maps of biomass available and energy content potential.

RESULTS AND DISCUSSION

Biomass Theoretical Potential

Table 1 shows the total annual production of residues or biomass residue theoretical potential of corn cob at the municipal (city) level and district level. Land area and production of residue yield per hectare are the main factors that influence biomass theoretical potential for corn.

Table 1.
Biomass Theoretical Potential

DISTRICT	An (ha)	Yn (MT/hr/yr)	Bn (MT/muni/yr)
District 1			
1. Talakag	7,754	3.28	25,433.12
2. Baungon	3,622	4.22	15,284.84
3. Sumilao	3,110	4.15	12,906.50
4. Manolo Fortich	2,860	4.09	11,697.40
5. Libona	2,411	4	9,644.00
6. Malitbog	1,666	3.4	5,664.40
Total Bn per District			**80,630.26**
District 2			
1. Cabanglasan	10,384	5.88	61,057.92
2. Malaybalay	17,091	3.44	58,793.04
3. San Fernando	9,657	4	38,628.00
4. Lantapan	2,907	3.59	10,436.13
5. Impasug-ong	2,635	3.66	9,644.10
Total Bn per District			**78,559.19**
District 3			
1. Kadingilan	9,752	4.01	9,105.52
2. Kitaotao	11,286	3.03	34,196.58
3. Don Carlos	6,472	4.4	28,476.80
4. Kibawe	7,482	3.72	27,833.04
5. Damulog	5,292	3.13	16,563.96
6. Quezon	3,658	3.36	12,290.88
7. Maramag	2,787	3.63	10,116.81
8. Dangcagan	2,006	4.2	8,425.20
Total Bn per District			**77,008.79**
District 4			
1. Valencia	7,470	4.16	31,075.20
2. Pangantucan	5,206	3.74	19,470.44
3. Kalilangan	4,457	3.5	15,599.50
Total Bn per District			**66,145.1**

At the municipal level, the localities of Cabanglasan, Malaybalay, Kadingilan, and San Fernando sequentially indicated the highest theoretical potential of biomass residue in the entire province. Cabanglasan was reported to have the highest biomass theoretical potential (Bn) mainly because of its reported high average residue yield per hectare in 2015, although it only follows after Malaybalay and Kitaotao in terms of dedicated area for corn production.

At the district level, District 2 has the highest total theoretical potential in tons per year and closely followed by District 3. Although District 3 had a much larger area for corn production than District 2 of more than of 6000 hectares in 2015, its average residue yield per hectare is half a ton lower than District 2. District 1 and District 4 on the other hand produced only around 40% of the total production of Districts 2 and 3.

Biomass Available Potential

Biomass available potential is the estimate of the total energy content of the biomass potential in an area expressed in mega joules per hectare per year (MJ/ha/year). Several parameters used (such as the theoretical potential, collection efficiency (Fg), residue available for production, low heating value, and total land area dedicated for crop production) dictate the availability of biomass available potential of an area. Table 2 displays the computed biomass available potential (Bv) in each municipality and the average Bv at the district tier. Sequentially, Don Carlos, Kadingilan, Damulog and Kibawe have the highest energy content of the biomass potential or Bv (mega joules per hectare) in the province. With collection efficiency factor equal in all four localities, what remains to have greater effect on the Bv are the biomass availability for production and total municipal / city land area. The greater the area of the locality the lesser the Bv becomes. At the cluster level, although land area is smaller than District 2, average Bv is remarkably high in District 3 with bigger average values in Fg and An.

Table 2.
Biomass Available Potential

DISTRICT	Bn (MT/muni/yr)	fg (%)	an (%)	LHVn (MJ/kg)	Ar (ha)	Bv (MJ/ha)
District 1						
1. Sumilao	12,906.50	1	0.54	12.6	19,695	4,458.79
2. Talakag	25,433.12	1	0.6	12.6	78,640	2,444.99
3. Baungon	15,284.84	1	0.2	12.6	32,830	1,173.25
4. Malitbog	5,664.40	1	0.65	12.6	58,185	797.31
5. Libona	9,644.00	0.33	0.1	12.6	37,437	107.11
6. Manolo Fortich	11,697.40	1	0	12.6	41360	-
Average By						**1,496.91**
District 2						
1. Malaybalay	58,793.04	1	0.39	12.6	96,919	2,980.93
2. Cabanglasan	61,057.92	0.3	0.3	12.6	24,330	2,845.86
3. San Fernando	38,628.00	0.34	0.6	12.6	70,506	1,408.24
4. Impasug-ong	9,644.10	1	0.4	12.6	105,117	462.40
5. Lantapan	10,436.13	1	0.1	12.6	32,835	400.47
Average By						**1,619.58**
District 3						
1. Don Carlos	28,476.80	1	0.7	12.6	21,372	11,752.08
2. Kadingilan	39,105.52	1	0.4	12.6	17,194	11,462.83
3. Damulog	16,563.96	1	1	12.6	24,419	8,546.86
4. Kibawe	27,833.04	1	0.4	12.6	30,413	4,612.45
5. Dangcagan	8,425.20	1	0.8	12.6	42,269	2,009.18
6. Kitaotao	34,196.58	1	0.33	12.6	78,878	1,802.65
7. Maramag	10,116.81	1	0.4	12.6	44,726	1,140.02
8. Quezon	12,290.88	0.01	0.2	12.6	62,686	4.94
Average By						**5,166.38**
District 4						
1. Valencia	31,075.20	1	0.5	12.6	58,729	3,333.51
2. Kalilangan	15,599.50	1	0.4	12.6	25,143	3,126.97
3. Pangantucan	19,470.44	0.33	0.17	12.6	46,172	298.08
Average By						**2,252.85**

To ascertain Fg, quantity of actual collection is taken against theoretical biomass collection. Interviews reveal that shelling method somehow affects Fg. Manual shelling, which is usually done at the households, keeps the cob intact to allow better control by farmers in terms of managing the residue. Mechanical shelling on the other hand, which happens either in the cultivation area or where solar dryer facilities are located reduces the cobs into smaller pieces and become difficult for the farmers to manage. Transporting these back to their dwellings is an additional burden (although not the usual practice).

In this case, many farmers decide to abandon the residue in the shelling area. Biomass residue available, that is net of what is left after application to farm (composting) and household use (e.g. fuel for cooking), or what the farmer is willing to sell, showed similarities among localities. Composting and fuel for household cooking are common uses of residue among all localities in Bukidnon. Uses of biomass do not vary much across localities as environmental, physical, and cultural factors are similar within the province.

Survey results revealed very few are selling residue as it is not a popular practice as yet; but then many farmers expressed openness to sell entire residue produced should there is a market demand and price is compelling. Price range acceptable to them is from Php.50 to Php1.50 per kilogram or around Php10.00 per sack depending on the farm's distance to the market. Market price of cob can have pronounced influence on the farmer's decision on use of residue. Those who are not willing to sell are noticeably those who are technologically aware and are practicing organic or sustainable farming techniques. Bv values automatically become zero for municipalities with zero or are not willing to sell or give away their biomass residue for energy production.

Energy Content Biomass Residue in kWh/MWh

Table 3 shows the energy content of corn cob residue in kilowatt hour (kWh) using the standard conversion base of 1 MJ = 0.2777777778 kWh. The total annual energy potential from corn cobs for the province is 625,560,244.2 kWh or 625,560.24 MWh.

Table 3.
Energy Potential from Corn Cob Residue

DISTRICT	Bv_MJ_Muni	kWh per District
District 1		**102,502,616.94**
1. Talakag	192,274,387	
2. Sumilao	87,815,826	
3. Malitbog	46,391,436	
4. Baungon	38,517,797	
5. Libona	4,009,975	
6. Manolo Fortich	-	
Total	**369,009,421**	
District 2		**144,220,522.03**
1. Malaybalay	288,908,999	
2. San Fernando	99,289,411	
3. Cabanglasan	69,239,681	
4. Impasug-ong	48,606,264	
5. Lantapan	13,149,524	
Total	**519,193,879**	
District 3		**298,793,184.33**
1. Don Carlos	251,165,376	
2. Damulog	208,705,896	
3. Kadingilan	197,091,821	
4. Kitaotao	142,189,380	
5. Kibawe	140,278,522	
6. Dangcagan	84,926,016	
7. Maramag	50,988,722	
8. Quezon	309,730	
Total	**1,075,655,464**	
District 4		**80,043,920.89**
1. Valencia	195,773,760	
2. Pangantucan	78,621,480	
3. Kalilangan	13,762,875	
Total	**288,158,115**	
Provincial Total	**2,252,016,879**	**625,560,244.20**

The amount of energy available from corn cobs in a year (two croppings) in Bukidnon is enough to supply the annual domestic energy demand of a municipality with a household (HH) population of 27,700 or less. Such municipalities are Dangcagan, Malitbog and Sumilao. Moreover, same amount of energy can only supply the annual energy demand of around 15% of the HH population of Malaybalay City or Valencia City. These estimates are using the report of the

Philippine Statistics Authority (PSA) that average annual HH energy consumption (in 2004) was 22,524 kWh and the average household size (in 2015) in Bukidnon was 4.6.

Geographic Distribution

Figure 2 presents the thematic maps of the various ranges of biomass theoretical potential and available potential in Bukidnon. Biomass theoretical potential (Bn) is sequentially high in Cabanglasan, Malaybalay, Kadingilan and San Fernando. All belong to District 2 except Kadingilan which is part of District 3. Biomass available potential (Bv) and consequently the energy potential (kWh) is foremost in District 3 where the most number of municipalities are located.

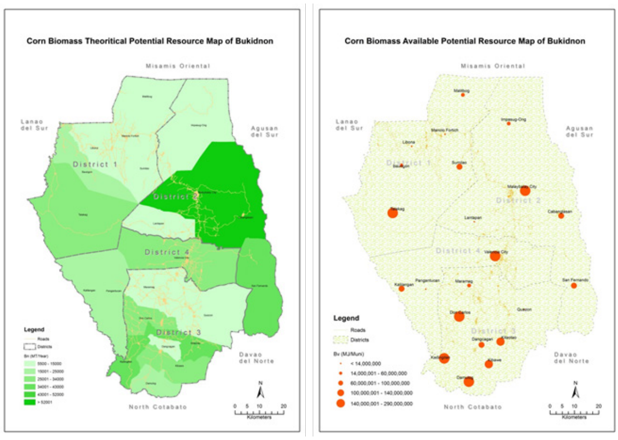

Figure 2. Biomass Potential and Available Potential Resource Maps

CONCLUSION

Figure 2 shows the study produced thematic maps showing the distribution and concentration of biomass corn residue and available potential for energy production in Bukidnon. It is established that the total annual production of corn biomass residues (theoretical potential) is about 502,343.38 tonnes, which corresponds to an annual available potential for energy production of 2,252,016,879.08 MJ at an average of 102,364,403.59 MJ per municipality / city. Concentration of biomass potential for energy production is in District 3 that amount to 1,075,665,464 MJ. Supposing all factors such as volume of corn production, collection efficiency, and availability are the same or higher energy from corn residue it can provide a significant contribution to the province's energy supply for domestic/household use. A small municipality or a quarter of the biggest municipality can be energized the whole year round. It identifying the most feasible and suitable location for a bio-energy plan, areas within District 2 and District 3 can be considered. Studies to develop site suitability analysis for power plant development, that may include other leading agronomic crops, e.g., rice and sugarcane, can build its work in this study. Further, this study recommends that, to improve accuracy, higher resolution imagery such as LiDAR images and data may be used in producing biomass resource and site suitability maps.

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