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Comparison of MODIS-Based Rice Extent Map and Landsat-Based Rice Classification Map in Determining Biomass Energy Potential of Rice Hull in Nueva Ecija, Philippines

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Abstract—The underutilization of biomass resources in the Philippines, combined with its growing population and the rise in fossil fuel prices confirms demand for alternative energy sources. The goal of this paper is to provide a comparison of MODIS-based and Landsat-based agricultural land cover maps when used in the estimation of rice hull's available energy potential. Biomass resource assessment was done using mathematical models and remote sensing techniques employed in a GIS platform.

***Keywords*—**Biomass, geographic information system, GIS, renewable energy.

I. Introduction

THE Philippines is an agricultural country with a total land area of 30 million hectares, one-third of which is used in crop cultivation. Rice, a staple food across the archipelago, is one of the major crops produced in the country. Its widespread cultivation to comply with the high demand in its production is centered on Region III (Central Luzon), particularly in the province of Nueva Ecija. Being the largest rice-harvesting province in the country, it also produces the largest amount of rice hull wastes among other provinces. However, rice hull is customarily discarded or burned by farmers after milling. The resolution in the country's need for alternative energy is to utilize its high energy potential from agricultural residues [1]. The potential capacity of the nation's biomass resources goes up to 4,450 MW [2]. Table I shows the estimated amount of biomass (in MT) required to produce one megawatt per year.

Biomass resource assessment is vital in determining the bioenergy potential of an area. Identifying the energy potential combined with the analysis of physical, environmental, and socio-economic aspects helps investors in developing strategies for potential power plant facility developments in the region [3]. There are two types of biomass potential that can be evaluated in the assessment, namely: theoretical and available potential. The theoretical potential shows the total annual residue of the area while available potential gives the actual amount of energy that can be derived from the residues.

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TABLE I
Estimated Biomass Feedstock Requirement per Year (DOE)

Crop Residue	MT/MW
Rice hull	8,150
Coconut husk	7,372
Bagasse	6,832
Sugarcane Trash	7,000
Corn Cobs	6,378

Different types of satellite imageries can be utilized in identifying rice crop areas, one of the initial processes involved in the assessment. Aside from locating residue sources, these images are also used in generating agricultural maps. These agricultural land cover maps are used as the primary input data in the calculation of theoretical and available potentials in a given area. Depending on the type of image, there is a possibility to produce different energy potential values because of the variations in spatial and temporal resolutions and other specifications. Spatio-temporal data using Landsat 8 and MODIS images were used in the analysis.

II. Methodology

A. Mathematical Models

The models involved in the study were employed in a GIS platform where the amount of resource and residue is spatially and statistically generated. In the evaluation, several factors are accounted for: the availability of residues for energy production, the amount of residue loss during collection (transportation and milling), crop yield, lower heating value, and the area of the province. A conversion coefficient for rice hull is multiplied to the crop yield to convert it into energy unit [4]. Reference [5] provided the equations for the computation of rice hull's theoretical and available potential.

Theoretical potential (B_n) is the total annual production of residues in the area. Equation (1) shows the formula for B_n,

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

where; A_n = cultivated area for crop n (ha), B_n = biomass theoretical potential for crop n (t or residue/year), Y_n = residue yield for crop n (t/ha/year).

The theoretical biomass potential shows the amount of residue produced but it does not reflect the total useable biomass for power production. Biomass from crop residues specifically rice hulls have numerous uses for activities like composting and cement production. Inefficiencies in residue collection also contribute to the loss in energy availability. Thus, it is important to assess rice hull's actual availability for energy production. Available potential (B_{av}) is the energy content of the residue. Equation (2) shows the formula for B_{av}.

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

where; a_n = biomass available for energy production from crop n (%), A_r = area of the region under consideration (ha), B_n = biomass theoretical potential for crop n (t of residue/year), B_{av} = biomass available potential (kJ/ha/year), f_g = efficiency of the biomass collection procedure (%), LHV_n = lower heating value of the residue from crop n (kJ/kg).

Equations (1) and (2) were used in all computations on both images using different GIS tools.

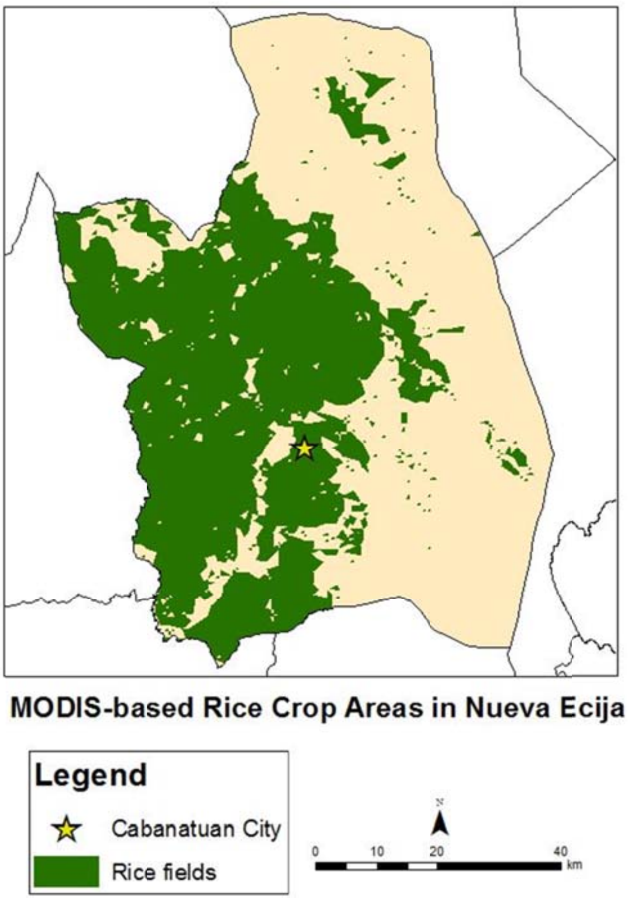

Fig. 1 Agricultural map using MODIS data

B. Classification of Spatio-Temporal Images

The increasing accessibility of remotely sensed satellite images allows more effective means in biomass energy evaluation. Aside from spatial measurements and explorations, satellite images are also used in monitoring several phenomena such as changes in land use. Spatio-temporal images vary depending on resolution and date acquired. The first type of image used in the analysis is the Moderate-resolution Imaging Spectroradiometer (MODIS). It is frequently used in producing land cover maps and in analyzing multi-temporal landscape changes. There are also studies about change detection in vegetation using MODIS data.

Another type of image used in the analysis is Landsat 8. It is frequently used in making land cover maps. The image provides a moderate-resolution imagery of the land surface as it consists of nine spectral bands with wavelengths ranging from 0.43-12.51 micrometers [6]. The main difference of the MODIS and Landsat images is the resolution. MODIS has a lower spatial resolution of 250 m compared to that of Landsat which is 30 m. However, MODIS includes temporal analysis wherein the data gathered covers a 12-year interval (2000-2012) while the Landsat 8 image was taken on a specific date (May 30, 2014). Figs. 1 and 2 show rice crop area maps generated from MODIS and Landsat data, respectively.

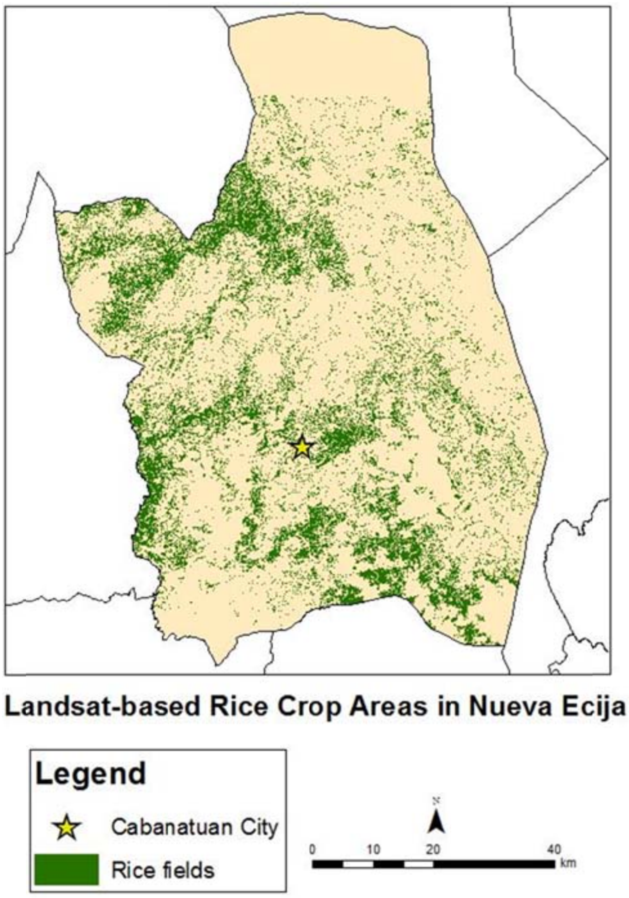

Fig. 2 Agricultural map using Landsat data

C. GIS-Based Model

A GIS-based methodology incorporating the mathematical models for theoretical and available potential was developed [5]. Rice crop areas were classified and mapped from MODIS and Landsat 8 data. The agricultural maps processed from the classification were used to extract the energy potential of the province. The model in determining both theoretical and available potential was based from the algorithm in [5]. Statistical parameters were spatially related and analyzed in a GIS platform (Fig. 3).

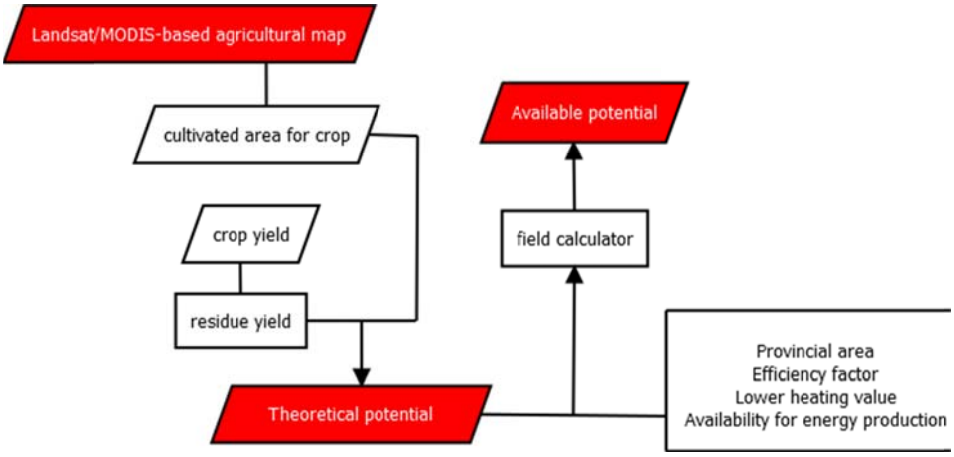

Fig. 3 GIS-based biomass resource assessment workflow

III. Results and Discussion

The methodology was applied to the province of Nueva Ecija. The biomass theoretical potential was computed using (1). The rice crop yield was obtained from the Bureau of Agricultural Statistics while the rice crop areas were derived from the agricultural maps based from MODIS and Landsat images. The residue yield was computed by multiplying the crop yield to the crop to residue conversion factor. Table II presents the calculated theoretical potential and the parameters used in MODIS and Landsat 8 data.

TABLE II
COMPUTED BIOMASS THEORETICAL POTENTIAL OF RICE HULL

Image Used	Crop Area (ha)	CY (MT/ha)	CRC	Y_n (MT/ha)	B_n (MT)
MODIS	246,576.274	6.07	0.225	1.36575	336,761.54
Landsat	15,986.337	6.07	0.225	1.36575	21,833.34

Note: CY = Crop Yield, CRC = Crop to Residue Conversion

The computation of the total annual residues in the province allows for the calculation of available potential using (2). The values for the efficiency of collection and availability for energy were based in [7] while the lower heating value of rice hull is a constant. Table III shows the available potential and the parameters employed in the calculation.

The MODIS image has a significantly larger theoretical and available potential compared to Landsat 8. Generating a higher value of theoretical potential does not indicate a higher value of available potential as there may be limitations during collection of residues and energy availability. However, since same values were used in both images, the model produced a higher available potential in MODIS. Although the spatial resolution is a great factor in the classification process, the temporal resolution of the image is also essential in the calculation of energy potential. Since MODIS data was gathered within a 12-year interval, possible land cover changes were recorded [8]. Therefore, crop areas were rice are planted all throughout the year were identified and taken into account. The Landsat image was taken during summer time which is the usual harvesting period of rice. Hence, fallow/bare land that could have been rice crop areas was classified in the agricultural map.

TABLE III
COMPUTED BIOMASS AVAILABLE POTENTIAL OF RICE HULL

Image Used	B_n (MT)	A_r (ha)	f_g (%)	a_n (%)	B_{av} (MJ/ha)
MODIS	336,761.54	511,208.134	81.9	81	7,210.703
Landsat	21,833.34	511,208.134	81.9	81	467.493

IV. Conclusions and Recommendations

The resource assessment model evaluated the energy potential of rice hull using MODIS and LandSAT- derived agricultural maps. The MODIS data has a higher temporal resolution at 12 years compared to Landsat 8 (taken on May 30, 2014). Its monitoring of vegetation changes, particularly rice areas is a major factor in the computation of higher potential values than Landsat. The Landsat-based agricultural map has low energy potential as the image used in classification was taken post-harvest which can is evident by the large area for fallow/bare lands. The resolution of MODIS is limited to 250-m affecting the determination of classes that may be delimited to a reduced quantity. On the other hand, Landsat has a 30-m spatial resolution giving more class variations and higher classification accuracy. In conclusion, there is a huge variation of energy potential between MODIS and Landsat. MODIS is effective in recording temporal changes in crop areas while Landsat generates a more precise agricultural map because of its high resolution.

The model can be applied in mapping bioenergy potential on a national scale. The values for theoretical and available potential can also be improved by doing field validation on crop yield, collection efficiency, and energy availability parameters. It is also advised to continue the study with suitability analysis to get the areas most suitable for facility development and optimality analysis to get the optimal location of future bioenergy facilities.

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