Quantitative image analysis to identify the feasible areas of rice straw biomass VSPP power plant at provincial level, Thailand

Sansanee Sansiribhan\(^1\,*\) and Anusorn Rattanathanaophat\(^2\)

\(^1\)Applied Physics Program, Faculty of Science and Technology, Suan Sunandha Rajabhat University, Bangkok 10300, Thailand.

\(^2\)Pilot Plant Development and Training Institute, King Mongkut’s University of Technology Thonburi, Bangkok 10140, Thailand.

*Corresponding author e-mail: sansanee.sa@ssru.ac.th

Abstract. The studying the feasible potential areas for rice straw power plants with a capacity of less than 10 MW\(_e\) of a provincial level propose in this work. The potential area for producing electric energy was analyzed using the Image technique. An imaging technique assess based on the technical and economic feasibility of potential areas, i.e., transportation, water supply and the 22 kV grid connection system of Provincial Electricity Authority (PEA). The results showed the geographic distribution of the potential location of rice straw biomass at the feasible areas in the case of Nakhon Sawan province. It also found that Nakhon Sawan province has very high potential of rice straw biomass for power plant total capacity of 41.1 MW\(_e\), especially, the areas within the collection rice straw radius of 25 km, i.e., Banphot Phisai district and Tha Tako district in Nakhon Sawan province have the available surplus rice straw residues for power generation with capacity of 8.3 MW\(_e\) and 5.4 MW\(_e\), respectively. Moreover, two districts are thus proposed to the suitable locations for rice straw power plant construction. The suitable areas of Banphot Phisai district and Tha Tako district were around 362.47 km\(^2\) and 206.71 km\(^2\), respectively.

1. Introduction
Biomass is one of the targeted biofuels which expects to help partly substituted fossil fuel for power generation, especially rice straw [1-3], in Thailand. Recently, the new projects of renewable energy development are introduced into Thailand Power Development Plan (PDP2018) and have targeted an additional total new capacity of 3,376 MW\(_e\) from biomass power plants within the year 2037 [4]. The Thai government has also promoted biomass-based power plant projects, i.e., the Small Power Producer (SPP) and Very Small Power Producer (VSPP), to support electricity to the Electricity Generating Authority of Thailand which is the national grid. The capacity of SPP is 10-90 MW\(_e\), while the VSPP capacity is less than 10 MW\(_e\). Rice straw has been assessed to be a high potential biomass fuel for power generation in Nakhon Sawan province in the Central region of Thailand [3, 5]. Nevertheless, although Nakhon Sawan province has a high potential area for the possible power plant from rice straw, such area locations have not yet been defined.

The purpose of this study is to study the feasible potential areas for rice straw power plants with a capacity of less than 10 MW\(_e\) in Nakhon Sawan province using image analysis techniques such as Geographic Information System (GIS) method and ImageJ analysis technique. The used of GIS as the analytical method has focused on identifying suitable locations for the rice straw power plant. GIS has
widely used for site selection problems in many study areas and the ability to integrate many required features for the planning of renewable energy projects or the best potential site [6-11]. The potential areas assessment based on the feasible technical and economic, i.e., transportation, water supply and the 22 kV grid-connected system of Provincial Electricity Authority (PEA). ImageJ is well known and available image processing tool to quantify features. This useful tool has been used to be capable of successfully quantifying and analyzing surface area, size, the fractal dimension of different features in many images obtained (i.e., SEM images, CLSM image, fluorescence images) [11-13]. Thus, the ImageJ technique has been used for quantifying the area of GIS image obtained. The study shows the combination of the image analysis of the GIS image facilitates the quantitative identification of a suitable area for supply the installation of VSPP rice straw power plant.

2. Methods
Nakhon Sawan province is the subjected area in this work, which locates on the lower northern part of Thailand, with total a geographical area of 9,597.7 km². The province is the main gateway to the Northern region and the hub of transportation in the lower Northern. It divided into 15 districts. There are minor rivers such as Ping and Nan rivers flow, which merged to form the major river, Chao Phraya River. It is thus the most important waterway in Thailand. Rice is the major crop of Nakhon Sawan province. The cultivated areas of rice are 4,229.7 km² (about 44.07% of the whole province area) as shown in Figure 1.

Figure 1. The map of cultivated areas of rice in Nakhon Sawan Province.

2.1 Evaluation of Power Plant Capacity
The potential of rice straw power generation is assessed in terms of biomass power plant capacity, i.e., rice straw [1]. The capacity of the rice straw power plant in Nakhon Sawan is evaluated base on the current quantity of surplus rice straw within the collection rice straw radius of 20-25 km. This is probably because to avoid an additional cost for transportation the lightweight rice straw [14]. The capacity of rice straw power plant is determined by using the following expression:

$$BP = \frac{\sum P \times SGR \times F \times LHV \times \eta}{T}$$

Where BP is biomass power from rice straw at district (MW); P is paddy production of district (tonne/yr); SGR is straw to grain Ratio; F is availability factor of rice straw; LHV is lower heating value.
of rice straw, MJ/tonne; $\eta$ is overall conversion efficiency of the power plant operated; $T$ is power plant operating time, seconds per annum. The operating conditions of the power plant are used as assumptions for this evaluation. Plant efficiency was around 20% [7], which could be operated to 292 days per year (Plant Factor 80%). The plants thus required a rice straw supply of 10,148 ton/year/MW (LHV of 12.33 MJ/kg and moisture content of 10%w.b.) [15].

2.2 Quantification of the Suitable Area

![Figure 2. Map overlay; (a) the map layer of the transmission lines, (b) transportation (The road network), (c) water supply and (d) overlay and identifying the suitability areas of image analysis.](image)

To determine the suitable potential site or site selection for a rice straw power plant, when performing site selection analysis was carried out by set various criteria form, which is the geographic information system can determine the best sites for the location of potential.

The definition of associated criteria for selecting suitable power plant location in terms of a summary of these economical, technical and ecologic feasibility objectives for the power plant is given as [6]:

Criteria 1: Acceptable proximity to main roads: maximum distance to roads should be 1,000 m.

Criteria 2: Acceptable proximity to transmission lines: if distance more than 800 m, then additional costs associated with connecting the system to the grid. It was not worth investing.

Criteria 3: Acceptable in terms of water supply: at least 100 m buffer (the environmental law).

The geographic information system (GIS) map overlay was then analyzed using ImageJ image analysis software (version 1.48v, National Institutes of Health, Bethesda, MD), which is capable of analyzing and evaluating areas under the three criteria as mention earlier. The GIS images were converted to grayscale and binary images using a threshold-based segmentation technique [11-12]. The map overlay is the combination of several map layers, e.g., transmission lines, road and water supply as shown in Figure 2(a), 2(b) and 2(c), respectively. As can be seen in Figure 2(d), the map overlay results created the new areas and visually similar to stacking several maps of the same region. The final maps are clearly shown by defining specific criteria and parameters that have to be included or excluded during the selection of a suitable site. These suitable sites that fulfill all of the criteria can be easily depicted using the image analysis technique. The GIS maps or GIS images were prepared by overlay and suitability analysis via the use of ImageJ software. The suitable (or unsuitable) areas for the power plant installation from rice straw are shown in Figure 2.

3. Results and discussion

3.1 Potential location of rice straw biomass in Nakhon Sawan province

The potential of biomass-fueled power plants at the district level was evaluated in terms of district power plant capacity. It was found that all districts had the potential of VSPP rice straw power plant. Moreover, the potential of the district level is classified into three groups. Group 1 (i.e., Banphot Phisai and Tha Tako), the districts in this group had the highest potential for power plant capacity over 5 MW. The districts in Group 2 (i.e., Lat Yao, Nong Bua, Takhl, Chum Saeng, Phaisali, Kao Liao, Mueang Nakhon Sawan, Krok Phra and Phayuha Khiri) had the available rice straw potential for power plant with capacity of around 1-5 MW. Those districts in Group 3 (i.e., Mae Wong, Chum Ta Bong and Tak Fa
and Mae Poen), the districts in this group had rice straw potential for a small power plant with capacity less than 1 MWₑ. The results also showed that the high potential areas of the rice straw power plant at the district level were found in Banphot Phisai and Tha Tako district. Those locations and the power plant capacity assessed are shown in Figure 3. As expected, Nakhon Sawan province had also a high potential of such power plant total capacity of 41.1 MWₑ.

![Figure 3. Power plant capacity of district in Nakhon Sawan province.](image)

| NO. | Distric            | Plant Capacity (MW) |
|-----|--------------------|---------------------|
| 1   | Banphot Phisai     | 8.3                 |
| 2   | Tha Tako           | 5.4                 |
| 3   | Lat Yao            | 4.1                 |
| 4   | Nong Bua           | 3.7                 |
| 5   | Taithi             | 3.6                 |
| 6   | Chum Saeng         | 3.0                 |
| 7   | Phakai             | 2.6                 |
| 8   | Kao Lao            | 2.2                 |
| 9   | Mueang Nakhon Sawan| 2.2                 |
| 10  | Krok Phra          | 2.0                 |
| 11  | Phayuha Khi       | 2.0                 |
| 12  | Mae Wong           | 0.9                 |
| 13  | Chum Ta Bong       | 0.7                 |
| 14  | Tak Fa             | 0.1                 |
| 15  | Mae Poen           | 0.1                 |
|     | TOTAL              | 41.1                |

**Figure 3.** Power plant capacity of district in Nakhon Sawan province.

![Figure 4. The suitable areas; (a) suitable areas in “Banphot Phisai” district and (b) suitable areas in “Tha Tako” district.](image)

### 3.2 Quantitative evaluation of the suitable areas
As mentioned above, Banphot Phisai and Tha Tako district were found to be the high potential areas of rice straw fuel for power generation. Banphot Phisai and Tha Tako district had the available surplus rice straw residues for power generation with the capacity of 8.3 MWₑ and 5.4 MWₑ as shown in Figure 3. The suitability analysis of the potential location of rice straw power plant in two districts were analyzed using an image analysis technique; resulting layers were obtained with the suitable geographical areas
are shown in Figure 4. Moreover, the suitable areas of the two districts were quantified. For Banphot Phisai, the suitable area of around 362.47 km\(^2\) accounted for 39.84\% of the total district area of 909.9 km\(^2\). The suitable area of Tha Tako was 206.71 km\(^2\), accounted for 34.04\% of the total area of 607.2 km\(^2\) as well. Those districts were thus proposed to be suitable locations for rice straw power plant construction.

4. Conclusion
The feasible potential areas for rice straw power plant capacity of less than 10 MW\(_e\) in Nakhon Sawan province were assessed and analyzed using the image analysis. The study had shown the combination of the image analysis of GIS data facilitated the suitable quantification areas for VSPP rice straw power plant installation. The results showed that Nakhon Sawan province had the high potential of rice straw biomass for the power plant total capacity of 41.1 MW\(_e\). The district of Banphot Phisai and Tha Tako, particularly, were more potential rice straw fuel and could suitably be areas for power generation than other districts. The results also showed the geographic distribution of the potential location of rice straw biomass in two districts, which was geographic analyzed based on three criteria decision making, i.e., road, water supply and transmission lines. The image analysis method is capable of identifying and quantifying all parameters that affect the suitable potential site for installation rice straw VSPP power plant. Future research is to study the other parameter, for example, urban planning and land use according to the Town and Rural Planning Law. The planning will be revised every five years in order to comply with the changed situation.

Acknowledgments
The authors express their sincere appreciation to the Institute of Research and Development, Suan Sunandha Rajabhat University for supporting the study. Our appreciation also goes to Planning and System Development, Provincial Electricity Authority (PEA), Bangkok for GIS information support.

References
[1] Suramaythangkoor T and Gheewala S H 2008 Potential of practical implementation of rice straw-based power generation in Thailand Energy Policy. 36 3193-3197
[2] Delivand M K, Barz M and Gheewala S H 2011 Logistics cost analysis of rice straw for biomass power generation in Thailand Energy 36 1435-1441
[3] Delivand M K, Barz M, Gheewala S H and Sajjakulnukit B 2011 Economic feasibility assessment of rice straw utilization for electricity generating through combustion in Thailand Appl. Energy 88 3651-3658
[4] The Electricity Generating Authority of Thailand. [Internet]. 2018 [cite 2019 Sep 1]. Available from http://www.egat.co.th/images/businessop/PDP2018-apr2019.pdf
[5] Sansiribhan S, Rewthong O, Rattanathanaophat A, Saensiriphan S 2014 Study of current the Rice straw potential for a small power plant capacity in the central region of Thailand Int. J. Environ. Ecol. Geological and Geophysical Eng. 8 27–30
[6] Aydin N Y, Kentel E and Duzgun H S 2013 GIS-based site selection methodology for hybrid renewable energy system: A case study from western Turkey Energy Convers. Manage. 70 90-106
[7] Hiloidhari M and Baruah D C 2011 Rice straw residue biomass potential for decentralized electricity generation: A GIS based study in Lakhimpur district of Assam, India Energy Sustain. Dev. 15 214-222
[8] Thanushkodi K and Babykalpana Y 2011 Classification of land use land cover change detection using remotely sensed data Int J Comput Sci Eng. 3 1638-1644
[9] Nagarajan M 2013 Identification and management of special economic zones (SEZ) using spatial and non-spatial techniques (a case study of Sriperumbudur Taluk, Chennai, Int. J. Eng. Technol. 5 2415-2423
[10] Krukanont P, and Prasertsan S 2004 Geographical distribution of biomass and potential sites of rubber wood fired power plants in Southern Thailand Biomass and Bioenergy 26 47-59
[11] Sansiribhan S, Devahastin S and Soponronnarit S 2010 Quantitative evaluation of microstructural changes and their relations with some physical characteristics of food during drying J. Food Sci. 75 E453-E461

[12] Hedberg-Buenz A, Christopher M A, Lewis C J, Meyer K J, Rudd D S, Dutca L M, Wang K, Garvin M K, Scheetz T E, Abrámoff M D, Harper M M and Anderson M G, 2016 RetFM-J, an ImageJ-based module for automated counting and quantifying features of nuclei in retinal whole-mounts Exp. Eye Res. 146 389-392

[13] Fontenete S, Carvalho D, Lourenço A, Guimarães N, Madureira P, Figueiredo C and Azevedo N F 2016 FISHji: new ImageJ macros for the quantification of fluorescence in epifluorescence images Biochem. Eng. J., 112 61-69

[14] The Energy for Environment Foundation website. [Internet]. 2015. [cite 2018 Jan 10]. Available from: http://www.efe.or.th.

[15] Weerawong N, Beem van N C, and Techato K 2014 Study of using Tillandsia usneoides L., case of heating value”, 5th International Conf. on Sustainable Energy and Environment 107-110 Bangkok Thailand