

GIS-BASED ASSESSMENT OF NAPIER GRASS POTENTIAL FOR ELECTRICITY GENERATION IN THAILAND: A CASE STUDY OF UNSUITABLE AREA FOR PLANTING ECONOMIC CROPS

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ABSTRACT

Thailand's Alternative Energy Development Plan (AEDP: 2012-2021) had been raised the target to generate 3000 MW power from Napier grass in 2021. To achieve the target, this paper assessed the Napier grass potential as an energy crop for power generation using geographic information system (GIS). Identifying the areas for planting Napier grass were conducted into 3 scenarios: (a) unsuitable area for planting the economic crops (excluded forest area); (b) unsuitable area for planting the economic crops (excluded forest and irrigation areas); (c) unsuitable area for planting the economic crops (excluded forest and irrigation areas) and located in agricultural land reform zone. Based on GIS and Thailand map data namely, six economic crop zones (rice, tapioca, sugar cane, maize, rubber and oil palm), agricultural land reform area, forest area and irrigation area, the results found that the areas for planting Napier grass of scenario (a), scenario (b) and scenario (c) were 12,848,938 rais, 11,892,548 rais, and 1,625,518 rais, respectively. Using soil properties and rainfall maps together with the crop yield data of King Napier grass to assess the Napier grass potential on those 3 scenarios, the results showed that the cultivation area of scenario (a), (b) and (c) had potential of 11,861,645 ton/y, 11,083,206 ton/y and 1,667,432 ton/y respectively. The estimated amount of Napier grass from these three scenarios could be produced 7,792,020 MWh/y, 7,279,560 MWh/y and 1,097,190 MWh/y with the capacity of about 1,186 MW, 1,108 MW and 167 MW via biomass thermal power plant respectively.

Keywords: Electricity generation/Napier grass/Geographic Information System (GIS)

INTRODUCTION

Thailand's electricity generation mostly comes from fossil fuels, which in 2013 was shared by 65.2% natural gas, 22.2% coal, and 1% oil [1]. Since Thailand is a net imported fossil fuel country, both energy security and global warming potential due to CO₂ emission will be the significant issues in country energy policy. To reduce the reliance on imported fossil fuels and greenhouse gases emissions from power sector. The government has promoted to generate the electricity from renewable energy sources. Among the renewable energy resources for electricity generation, biomass has high reliability and availability in Thailand which is an agricultural country. Two sources of agricultural residues are available: agricultural crop field and agro-factory. However, the density of agricultural crop residue per unit area is low and therefore

difficult to collect and transport to the power plant. These associated cost can strongly affect the financial feasibility of biomass power generation project [2]. Thus, the agricultural residues from factories are already being used as fuel to generate electricity in Thailand such as bagasse and rice husk [3].

Energy plantations such as fast growing plants and grasses have received the attention in recent year to increase the potential of renewable power generation. Napier grass (*Pennisetum Purpureum* Schum) is a native plant of Africa, which has the advantages of fast growth, disease and drought resistance, growth in a wide range of soil types, and harvestable biomass up to 4 times a year, thus it has been considered as an energy crop [4,5]. Thailand's Alternative Energy Development Plan (AEDP: 2012-2021) has targeted power generation from Napier grass up to 3000 MW

by 2021 [6]. To prevent the reduction of food security, Napier grass should be planted in the unsuitable area for food crop. The Ministry of Agriculture and Cooperatives of Thailand has adopted the agricultural zoning for 6 economic crops, namely rice, sugar cane, maize, cassava, rubber and palm oil. Based on land suitability and crop requirement parameters for their planting, the zoning is classified into 4 groups: (a) high suitable area; (b) moderate suitable area; (c) low suitable area; and (d) unsuitable area [7]. Thus, the unsuitable area is promising to utilize for energy crop plantation.

Geographic Information System (GIS) is an efficient tool for supporting the increased use of the renewable energy sources, which has been applied in assessment of rice straw potential for decentralized electricity generation [8], biomass potential from phytoremediation of contaminated agricultural land [9]; identifying the optimal location for solar and wind farms [10], biofuel production [11], biomass utilization [12]; implications of land allocation for energy crop [13]; and also environmental assessment of energy crop implementation on local scale [14].

To achieve the AEDP (2012-2021) target of Napier grass-based power generation, this study was conducted to assess the Napier grass potential as an energy crop for power generation using geographic information system (GIS) by focusing on unsuitable area for planting the 6 economic crops mentioned above, which excluded the forest area. King Napier grass using as biomass fuel in this study is a famous variety for Thai farmers. It can

grow on various soil types such as sandy soil, sticky soil with low pH value. The power generation potential was evaluated based on a small scale thermal power plant using direct biomass combustion that commonly used in Thailand.

METHODS

In this study, the unsuitable area for the 6 economic crops of 19,583,401 rai [15] was considered to utilize as cultivation areas of King Napier grass. The power generation potential from the energy crop was estimated based on the following 3 scenarios:

a) Overall unsuitable areas for planting the economic crops excluding forest area were utilized as the energy plantation area.

b) Since there are some irrigation areas, which should be used for food crop, in the overall unsuitable areas of scenario (a), therefore the energy plantation area in this scenario was excluded forest and irrigation areas.

c) As agricultural land reform areas are managed by the government office, they should be well assigned for energy plantation area. Thus, agricultural land reform area within the area of scenario (b) were considered as the energy plantation area in this scenario.

Fig.1 outlined the assessment procedures, which divided into 2 steps: (1) estimating King Napier grass production potential and (2) assessment of power generation potential from King Napier grass estimated form (1).

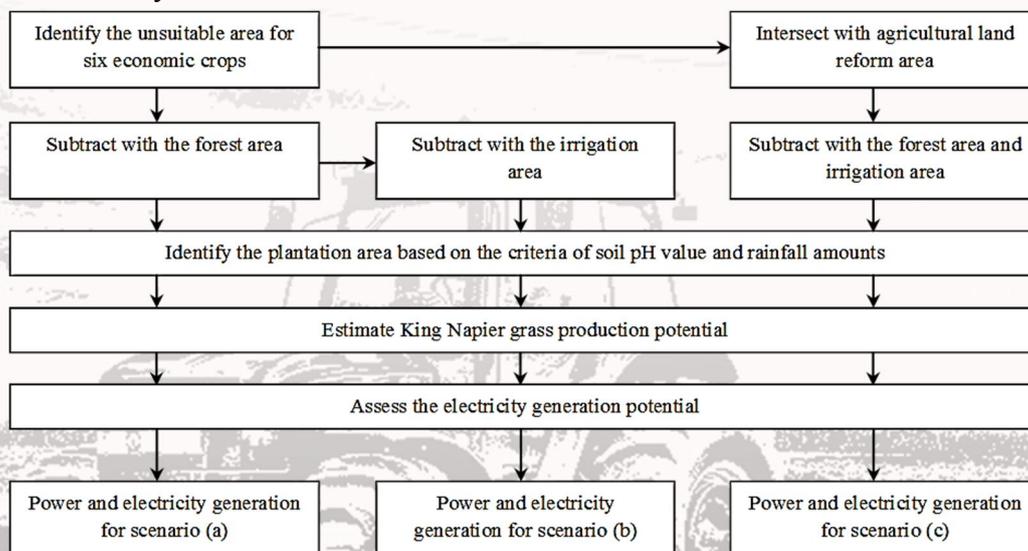


Fig.1 The schematic diagram of assessment procedure for power and electricity generation from King Napier grass.

Estimating King Napier grass production potential

As previously mentioned, King Napier grass can grow in various soil types and can tolerate dry condition. Thus, the criteria for identifying plantation area used in this study were soil pH value in the range of 4.5-8.0 and average annual rainfall above 1,000 mm, which assumed to produce the average annual grass yield of 1,911.5 kg/rai/y at moisture content of 21%w.b. [16, 17].

The 7 types of digital map data at scale of 1:50,000 used in this estimation were obtained from various government departments as shown in Table 1. Based on these data with plantation criteria and yield assumption, the GIS-based approach was used to identify the location, plantation area and then assessed the King Napier grass production potential of 3 scenarios stated above.

Assessment of electricity generation potential from King Napier grass

The following assumptions were used in the preliminary assessment:

1. The technology used to generate the power from King Napier grass was a small scale thermal power plant using direct combustion boiler and steam turbine with overall efficiency of approximately 18% [18].
2. Operating hours per year based on capacity factor of 75% for biomass power plant was 6,570 h/y [18].
3. Low heating value of King Napier grass at 21%w.b. was 13.14 MJ/kg.

Potential of electricity generation from King Napier grass was assessed by using the following equation

$$P = \left[\frac{F \times \eta \times LHV}{3.6 \times H} \right] \dots(1)$$

Where P was power generation (kW); F was fuel consumption (ton/y); η was overall efficient of the power plant (decimal); LHV was low heating value (MJ/kg); and H was operating hours per year (h/y). The electricity generation potential was then calculated with equation (2)

$$E = P \times H \dots(2)$$

Where E was the amount of the generated electricity per year.

Table 1 The 7 types of digital map at 1:50,000 scale for identifying the plantation area of King Napier grass.

Map Data	Sources
Topographic map	
Soil series map	
Map of unsuitable area for the six economic crop zones (rice, tapioca, sugar cane, maize, rubber and oil palm)	Land Development Department
Land Development Department	Royal Forest Department
Map of Agricultural Land Reform area	Agricultural Land Reform Office
Map of Irrigation areas	Royal Irrigation Department
Isohyet map	Meteorological Department

RESULTS AND DISCUSSION

Total unsuitable areas of 19,583,401 rai for the 6 economic crops, most of which are located in the north-eastern region of Thailand, were indicated in Fig.2. These areas were then classified based on the 3 scenarios as shown in Table 2. It was found that about 34.4% and 4.9% of total unsuitable areas was the forest and irrigation areas, respectively, thus the area of scenario (a) and (b) was 12,848,938 rai and 11,892,548 rai, respectively. However, when the agricultural land reform was considered as defined in scenario (c), the remaining area was significantly reduced from 11,892,548 rai in scenario (b) to only 1,625,518 rai.

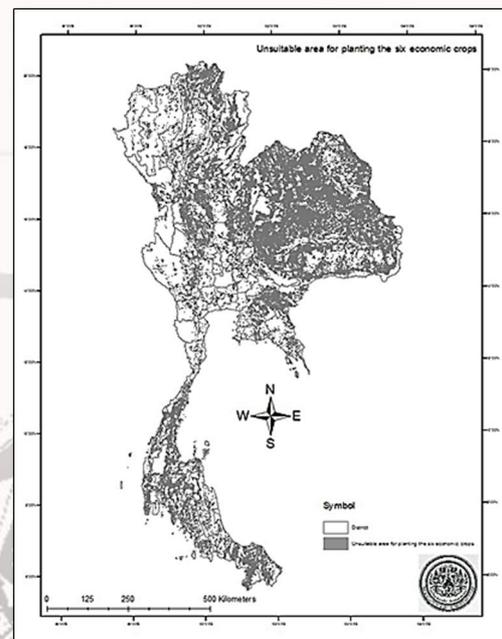


Fig.2 Map of unsuitable areas for the 6 economic crops in Thailand.

Table 2 Unsuitable areas for the 6 economic crops based on three scenarios.

Scenarios	Total area (rai)
(a) unsuitable area for planting the economic crops (excluding the forest area)	12,848,938
(b) unsuitable area for planting the economic crops (excluding of the forest and irrigation area)	11,892,548
(c) unsuitable area for planting the economic crops (excluded forest and irrigation areas) and located in agricultural land reform zone	1,625,518

Potential of King Napier grass production

Based on the 3 scenarios of plantation area in Table 2, the plantation criteria, and average annual grass yield, the map of suitable area and estimated total King Napier grass potential in term of annual yield for each scenario was shown in Fig.3-5 and Table 3, respectively. For scenario (a) and (b), the areas which met the criteria for planting King Napier grass were approximately 31.7% and 29.6% of the total unsuitable area, respectively, and mostly located in northeastern part of Thailand for both scenarios. While the plantation area of scenario (c) was only 4.5% of total unsuitable areas and also spread in the northeastern part. The corresponding potential of King Napier grass production at moisture content of 21%w.b. from these areas were 11,861,645, 11,083,206 and 1,667,432 ton/y for scenario (a), (b), and (c), respectively.

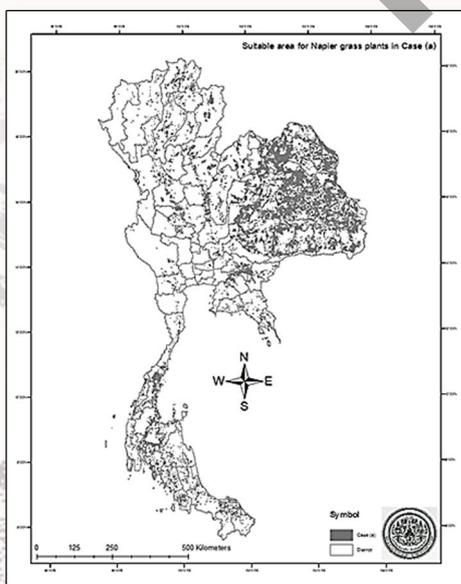


Fig.3 Map of plantation area of scenario (a).

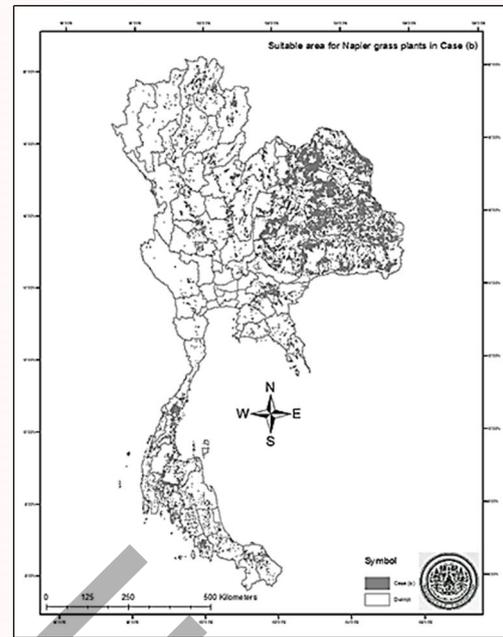


Fig. 4 Map of plantation area of scenario (b).

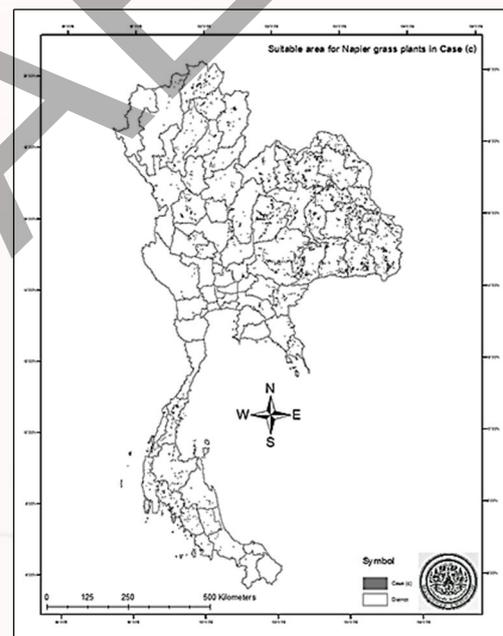


Fig.5 Map of plantation area for scenario (c).

Electricity generation potential from King Napier grass

According to the estimated annual production of the King Napier grass (see 3.1), the potential of power generation using direct combustion thermal power plant were assessed as shown in Table 3. The generated electricity of scenario (a), (b) and (c) were estimated to be 7,792,020 MWh/y, 7,279,560 MWh/y and 1,097,190 MWh/y, respectively, which in term

of power were 39.53%, 36.93% and 5.57% of the AEDP target of 3000 MW.

CONCLUSIONS

The GIS-based assessment of electricity generation potential from King Napier crop planted on the unsuitable area for 6 economic crops were conducted in 3 scenarios: (a) unsuitable area for planting the economic crops excluding forest area, (b) Unsuitable area for planting the economic crops excluding forest

and irrigation areas, and (c) unsuitable area for planting the economic crops located in agricultural land reform zone excluding forest and irrigation areas. Based on the total unsuitable areas of 19,583,401 rais, only 31.7%, 29.6% and 4.5% of the total areas could be utilized for planting King Napier grass based on scenario (a), (b) and (c), respectively, and the corresponding estimated potential of power generation from these three scenarios were relatively lower than the AEDP target.

Table 3 Potential of electricity generation using King Napier grass production from the unsuitable area for the six economic crops based on 3 scenarios.

Scenario	Plantation area (rai,)	Average annual yield of Napier grass at moisture content of 21%w.b. (ton/year)	Electricity generation power (MWh/y)	Power generation (MW)	ADED target of 3,000 MW (%)
a) Unsuitable area for planting the economic crops excluding forest area	6,205,413	11,861,645	7,792,020	1,186	39.53%
b) Unsuitable area for planting the economic crops excluding forest and irrigation areas.	5,798,172	11,083,206	7,279,560	1,108	36.93%
c) Unsuitable area for planting the economic crops located in agricultural land reform zone excluding forest and irrigation areas.	872,316	1,667,432	1,097,190	167	5.57%

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