

**Bioenergy Atlas of Agricultural Residues in Thailand**

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**Abstract:** As an agricultural based country, Thailand has a high potential for energy production from agricultural residues. To adequately utilize this resource, it is essential to identify the spatial distribution of agricultural residues for the whole country. To this end, a bioenergy atlas of agricultural residues in Thailand has been developed in this study. The atlas provides data related to the land use, yield of agricultural production, water resources, soil, infrastructure, and other related information. As geographic information system (GIS) provides the ability to combine sets of information with their associated location, it is used as basic tool to develop this atlas. The latter is established first for the whole country considering the following residues: rice husk, bagasse, palm residue, and forest residues. For each residue, the distribution of corresponding potential energy has been computed. To illustrate its use at the provincial scale with the perspective of site selection for setting up a biomass power plant, the case of Roi-et province is presented in details. The result shows where the power plants can be located with respect to availability of resources and accessibility to infrastructure.

**Keywords:** Agricultural residues, Atlas, Bioenergy, GIS, Thailand.

**1. INTRODUCTION**

Thailand's annual energy consumption has been rising during the past decade, and tends to retain a similar pace continually. While energy demand has risen sharply, domestic sources of supply are limited, thus forcing a significant reliance on imports. To face this increasing demand, Thailand needs to produce more energy from its own resources, more specifically of the renewable ones. Types of renewable energy resources include hydro- and tidal energy, wind energy, solar energy, geothermal energy and biomass energy. Located in the tropical region, Thailand has a high potential for energy production from biomass.

Each Table 1 reports estimation and projection of energy that is potentially available from different types of biomass in Thailand. From Table 1, it can be noticed that the largest biomass resource is agricultural residues, which is quite expected since Thailand is an agriculture-based country. Similarly to other renewable energy sources, the use of biomass for electricity production does not contribute to increase the overall concentration of carbon dioxide (CO<sub>2</sub>) in the atmosphere. Actually, the same amount of CO<sub>2</sub> emitted during the combustion that converts biomass into energy is used for the re-growth of biomass. Therefore, the use of bioenergy will prevent global warming.

**Table 1** Estimation and projection of energy available from biomass in Thailand [1].

Type of resources	Renewable energy demand and projection (PJ)		
	1997	2005	2010
Agriculture residuals	524.50	501.70	562.50
Animal waste	13.00	13.00	13.00
Biomass conservation	-	84.70	156.40
Biomass substitution	-	77.60	109.30
MSW	19.00	20.60	21.30
Waste water	7.80	7.80	7.80
Black liquor	8.80	8.80	8.80
Palm oil effluent	1.30	1.30	1.30
<b>Total</b>	<b>574.40</b>	<b>715.50</b>	<b>880.40</b>

In order to adequately utilize biomass resources for energy production, its availability and geographical distribution are of concern.

In this study a bioenergy atlas of agricultural residues in Thailand has been developed using geographic information

system (GIS) as the core base.

In the past, GIS has been applied to many different fields such as environment, urban site selection, transportation line, etc. Also, there are a number of efforts to use GIS for spatial analysis of biomass energy supply systems, e.g.:

- To locate the appropriate sites and sizes of rubber wood fired power plants in Southern Thailand [2].
- To map resource for analysis of farm livestock manures to identify sources of collectable farmyard manure in order to determine the potential sites of centralized anaerobic digestion schemes in United Kingdom [3].
- To assessment of biomass potential for power production from agricultural residues in the island of Crete [4].
- To evaluate the cost of delivering energy crop feedstock on a regional scale in USA [5].

This paper describes first the methodology set-up for this development, and then the results at national and local scales are detailed and discussed.

**2. METHODOLOGY****2.1 Use of GIS as the core base of this atlas**

A Geographic Information System (GIS) is a computer-based tool for manipulating spatially referenced data from the "real" world to help answer map-based questions [2]. A GIS is designed for enabling to store, retrieve, and display spatial data, facilitating the query and analysis of the spatial data and effectively synthesizing multiple layers of information [6].

In order to develop the bioenergy atlas of agricultural residues in Thailand, a framework has been designed including the four steps as follows: (1) data collection, (2) data pre-processing, (3) GIS database set-up, and (4) GIS data analysis and processing. The framework used for this study is shown in Fig. 1.

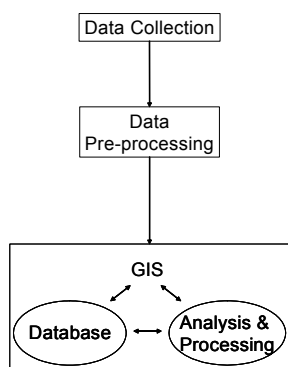


Fig. 1 Methodological framework of the study.

## 2.2 Creation of bioenergy atlas of agricultural residues

### 2.2.1 Software tool

In this study, the GIS software ArcView has been used to develop the bioenergy atlas of agricultural residues. As with any other GIS software, ArcView allows to manage geographical data (maps) along with their descriptive information. In other words, it enables to visualize, analyze, explore, query and visually interpret spatial or geographical data.

### 2.2.2 Data required for the creation of the atlas

The creation of bioenergy atlas requires two main types of data as follows:

- Geographical data necessary for the mapping, i.e. political boundaries, land use, road networks, etc.
- Descriptive data or attribute data that are associated to a given geographical information, i.e. types of crop, production yield of each crop, crop-to-residue ratio, heating value of each residue, etc.

In this study, all digital maps are collected from the Land Development Department; statistical data such as type of crop and production yield from the Department of Agriculture Extension; and physical and chemical characteristics of agricultural residues from Energy for Environment Foundation.

### 2.2.3 Bioenergy area mapping

A mapping of bioenergy area can be processed by using the land use digital map at a scale of 1:50,000 and attribute data related to energy content of each type of residue, following Eq. 1:

$$\text{Energy} = \text{Amount of biomass} \times \text{LHV} \quad (1)$$

Where LHV is the Low Heating Value of that type of biomass.

In the case of agricultural residues in Thailand, the amount of biomass usable for energy production can be calculated from Table 2. In this table, type of residues, crop-to-residue ratio, surplus available for energy production and energy content of the residue cane, rice, palm and coconut are reported. From this table, it can be seen that rice straw constitutes for most available residues while palm shell possesses the highest energy content. The result of the calculation is to be associated to the geographical data such as the land use map to generate the atlas of the energy that can potentially be extracted from a type of agricultural residue. For example, the result related to rice straw computed from Table 2 associated to the map of rice cultivation area will

generate a map of potential bioenergy available from rice straw.

Table 2 Crop-to-residue ratio, surplus availability, and energy content of agricultural residues in Thailand [3].

Agricultural Products	Agricultural Residue	Crop-to-residue Ratio	Surplus Availability Factor	Energy Content (MJ/kg)
Sugar Cane	Bagasse	0.250	0.207	9.25
Rice	Rice husk	0.230	0.469	14.27
	Rice straw	0.447	0.684	10.24
Palm	Empty fruit bruch	0.248	0.584	17.86
	Fibre	0.147	0.134	17.62
	Palm shell	0.049	0.037	18.49
Coconut	Coconut shell	0.160	0.378	16.23

## 3. LAND-USE ATLAS OF THAILAND

This atlas was developed to visualize different types of land use in Thailand. The digitized map of Thailand at the scale of 1:250,000 from the Land Development Department was used to locate different types of land use practiced in Thailand. Fig. 2 shows the 3 major types of land-use in Thailand: (1) Forest area (2) Agricultural area and (3) other areas. Forest area includes all types of forest such as deciduous, mangrove, evergreen, tropical, and secondary forest. Agricultural area covers plantations of crops such as rice, cassava, corn, sugar cane, palm, etc. Other areas of Fig. 2 indicates urban, clearing, water or any other that cannot be identified as forest or agricultural areas. From Fig. 2, it can be observed that the major part of the land is dedicated to agriculture. Actually, there are 4 main types of agriculture in Thailand as shown in Table 3: (1) field crops including maize, cassava, sugar cane, or soy bean, (2) rice (3) perennial covering coconut, rubber, oil palm and cocoa, and (4) pasture. From Table 3, it can be underlined that the major agriculture is rice cultivation and that the major area is located in the Northeast which can be easily visualized using Fig. 2.

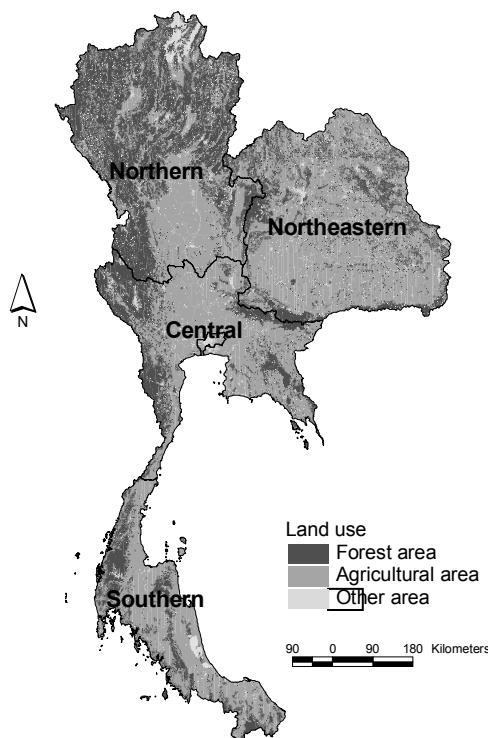


Fig. 2 Major land use in Thailand.

**Table 3** Type of agriculture vs. geographical location in Thailand

Type of agriculture	Regions				
	North	Northeast	Central	East	South
Field crop (rai)	20,036,318	30,894,340	11,485,471	5,308,758	160,642
Rice (rai)	16,434,526	40,520,843	14,873,477	5,583,579	7,057,075
Perennial (rai)	-	-	702,428	960,385	14,696,933
Pasture (rai)	14,724,446	21,250,255	3,355,121	5,565,188	4,933,812

Note: 1 rai equals 0.16 ha or 1600 square meter

#### 4. CASE STUDY: ROI-ET PROVINCE IN THAILAND

Roi-et province is located in the northeastern region of Thailand. This region has a large agricultural sector (mainly sugarcane, rice, and cassava) and numerous eucalyptus plantations which make it a suitable area for bioenergy projects [7]. Roi-et province is about 500 kilometres from Bangkok having a total land area of 8,799.5 km<sup>2</sup> or about 5,187,155 rai, accounting for 5.1% of the northeastern region. The general geographic feature of Roi-et province are the highlands about 130-160 metres above the sea level. Most areas in the middle of the province are shallow undulating and rolling lands which cover about 60% of the province. The administration of Roi-et is divided into 17 districts as shown in Fig. 3, 3 minor districts, 193 sub-districts, 2,349 villages, 1 provincial administration organization, 1 Muang municipality, 16 sub-district municipalities, and 186 sub-district administration organizations.



**Fig. 3** Political boundary of the 17 districts and the municipality of Roi-et province.

The biomass production map was generated by using the digitized land use map at a scale of 1:50,000 from the Land Development Department. The result is shown in Fig. 4, which shows that more than 90% of the province is dedicated to rice cultivation and consequently that the most potential residues in Roi-et province are rice husk and rice straw. The potential energy available from these residues can be calculated as described in the methodology section. Fig. 5 shows the result obtained for the rice husk and Fig. 6 for rice straw. From these Figures, it could be observed that Amphur (District) Pho Chai, Moei Wadi, Si Somdet, Thawatchaburi and Panom Phrai, have the highest potential energy from rice

residues since they contribute the area where rice production is the highest in the province. In the case of rice husk, the highest potential energy ranges from 700 to 900 MJ/rai/year while for rice straw, it ranges from 1500 to 2000 MJ/rai/year. These results indicate that the most potential resource of biomass energy of Roi-et is rice straw and that most suitable locations for setting up a biomass power plant may be at those 5 Amphurs. However, it should be underlined that the potential energy from rice straw stated in Fig. 6 is the energy that can be obtained from the total amount of rice straw available in the field. In practice, rice straw is generally left in the field, i.e. not collected. Consequently, if rice straw should be used for energy production, a collection system should be set up first. Also, Fig. 5 shows the in-field bioenergy from rice husk. However, this residue is available once the rice is processed at the rice mill. Therefore, it is more realistic for energy production to consider the amount of rice husk available at the rice mills. Fig. 7 shows the location of rice mills and their individual installed capacity. From this Figure, it can be observed that high capacity (> 4,000 tons/year) rice mills are distributed all around the province, contrary to the in-field availability (Fig. 5), and that rice mills are generally located close to the main roads. In a given Amphur, the amount of rice husk available at the rice mills is higher than in the field since the rice mills can also collect rice from other areas or provinces. Fig. 8 shows the comparison of the rice husk available in the field with that available at the rice mills in each Amphur. From this Figure, it is revealed that the availability at the mills is really higher. For example, in the case of Thawatchaburi, the energy from in-field rice husk is about 138,000 GJ/year or 38 GWh electricity but the one from the rice mills is 226,000 GJ/year or 63 GWh electricity, i.e. nearly 2 times more. Taking into account the amount available and easy access to road aspects, rice mills constitute one of the most suitable locations for setting up biomass power plants.

In order to investigate the possibility of setting up a biomass power plant in Roi-et, we have developed 2 scenarios for which the biomass resource is rice straw. The first scenario consists in using the rice straw availability and the corresponding potential energy of each area to define the type and capacity of power plant. For example, in the case of Amphur Thawatchaburi, which is one of the 5 Amphurs where 1,500 to 2,000 MJ/rai/year from rice straw are available, a power plant of up to 7 MW installed capacity can be set. However, for setting up a biomass power plant, the resource availability is not the only required parameter, but the access to roads and water resource also plays an important role. Fig. 9 shows potential locations suitable for rice straw power plant set up, based on resource availability and access to roads and water resource. From this Figure, it can be seen that about 50% of Roi-et's area is suitable for biomass power plant of 1-5 MW capacity.

The second scenario consists in defining first the location and the capacity of the biomass power plant to be set up. These two parameters will determine the amount of biomass to be used, and hence the areas from where the biomass can be collected. For example, in the case of Thawatchaburi, if a 10 MW power plant should be set, an area of 10 km radius around this Amphur can be outlined and the corresponding energy available can directly be calculated by the bioenergy atlas developed in this study. Using the developed bioenergy atlas, the maximum radius which defines the maximum amount of biomass available can also be calculated, and also the corresponding transportation cost.

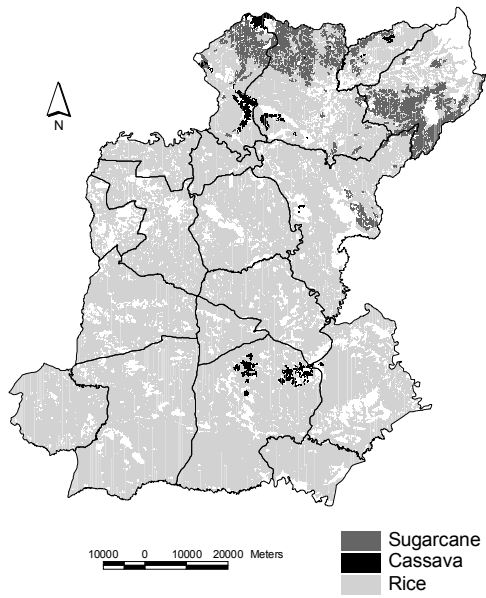


Fig. 4 Agricultural Areas of Roi-Et.

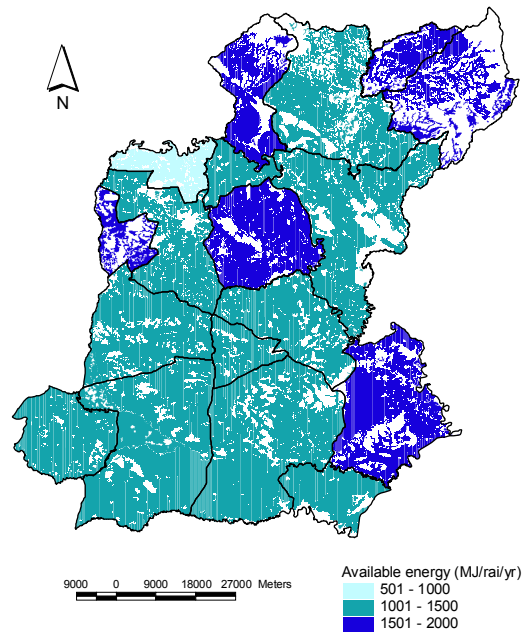


Fig. 6 Potential energy available from rice straw.

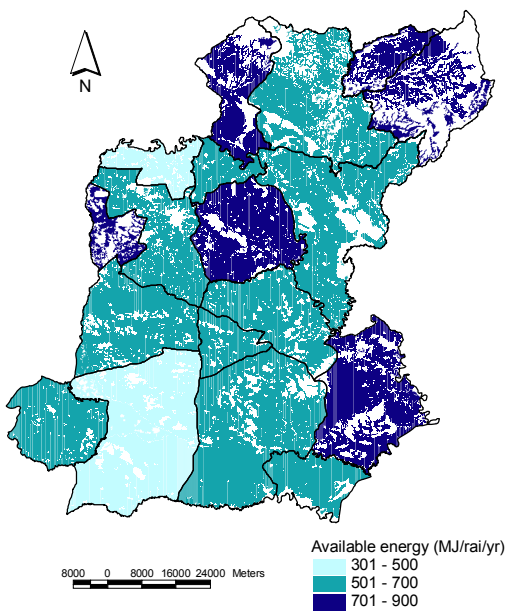


Fig. 5 Potential energy available from rice husk.

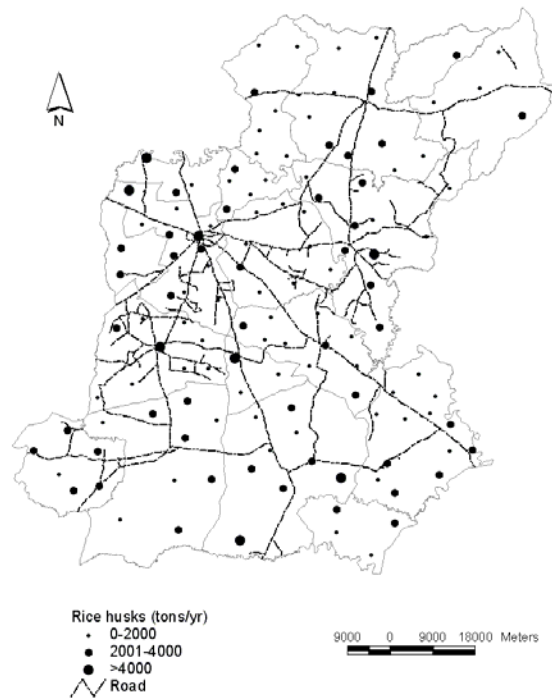


Fig. 7 Amount of rice husk from rice mills.

5. CONCLUSION

Since GIS is designed to combine geographical data to their descriptive data, the developed bioenergy atlas helps visualizing the atlas where biomass resource for energy production is available. In this study, a bioenergy atlas of agricultural residues in Thailand has been developed. Based on the land use map, the bioenergy atlas directly shows the amount of biomass and corresponding energy content. As GIS allows to overlay different layers of information, access to roads and water can be visualized and taken into account together with resource availability. Thanks to this property, the developed bioenergy atlas may be used to support decision making process, for example simulating different scenarios. The case study of Roi-et underlined this capacity, in particular to support the decision making process of site selection for biomass power plant.

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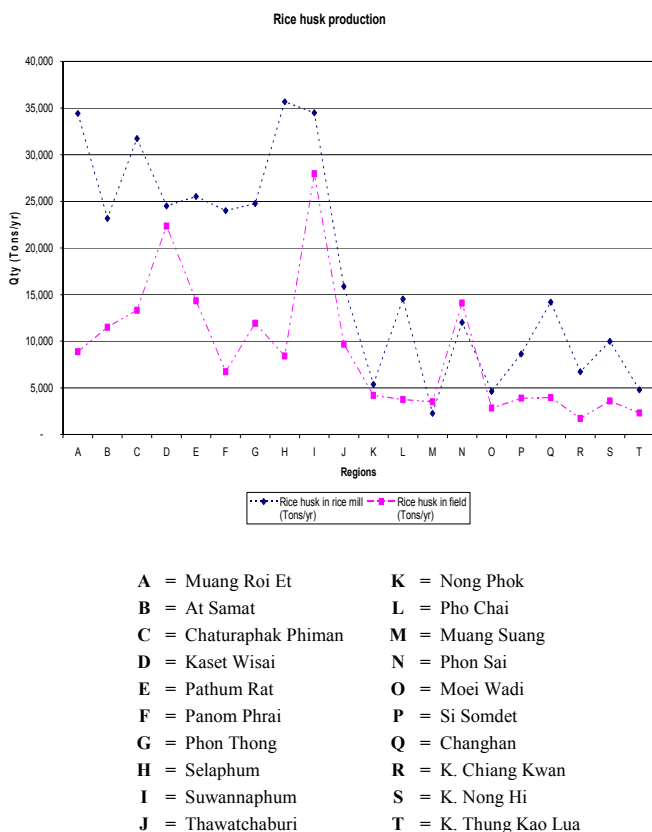


Fig. 8 Rice husk available in the field vs. at the mills in each Amphur of Roi-et.

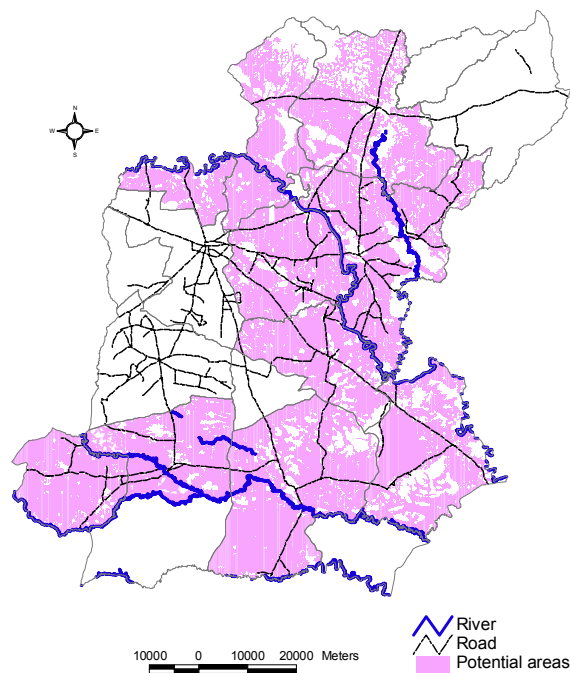


Fig. 9 Potential locations for rice straw power plant set-up considering resource availability, and road and water accessibility.

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