A-GIS BASED POTENTIAL EVALUATION OF NAPIER GRASS PLANTATION IN THAILAND

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According to the Alternative Energy Development Plan (AEDP 2012-2021) initiated by the Ministry of Energy (MoE), the future power generation sourced by alternative energy resources is planned to be increased up to 25% of total power generation in next 10 years. Among various alternative energy resources, biogas will contribute as high as 3600 MW of which 83% or 3000 MW will be produced from Napier grass. By an approximate estimation, an enormous area of 480,000 ha throughout Thailand is needed for Napier grass plantation in order to achieve the AEDP 2012-2021's target. This study aimed to develop a method in locating suitable areas of Napier grass plantation and estimating the potential of its productivity using geographic information system (GIS) technique via ArcGIS software. Integrating with statistical data obtained from pilot plantation sites, it was found that the total suitable area, including all different classifications was 51,324,101 ha and the total yield potential was 30,784,515 tons/year. The largest usable area was found at North-Eastern region which approximately 45% of total usable area.

Graduate School	Student's Signature………………………………
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Chapter 1
Introduction

1.1 Background & Rationale

Recently, the world energy crisis caused by fossil fuel overconsumption is spreading. Thailand is also facing the same problem since fossil fuel dependency tends to increase annually. As of year 2011, over 80 percent of oil consumption in Thailand were imported as shown in Fig.1. Development of renewable energy technologies will help reducing the imported energy also sharing the risk of the rely on role energy source such as natural gas by which more than 70 percent of Thailand's current power generation is produced [1]

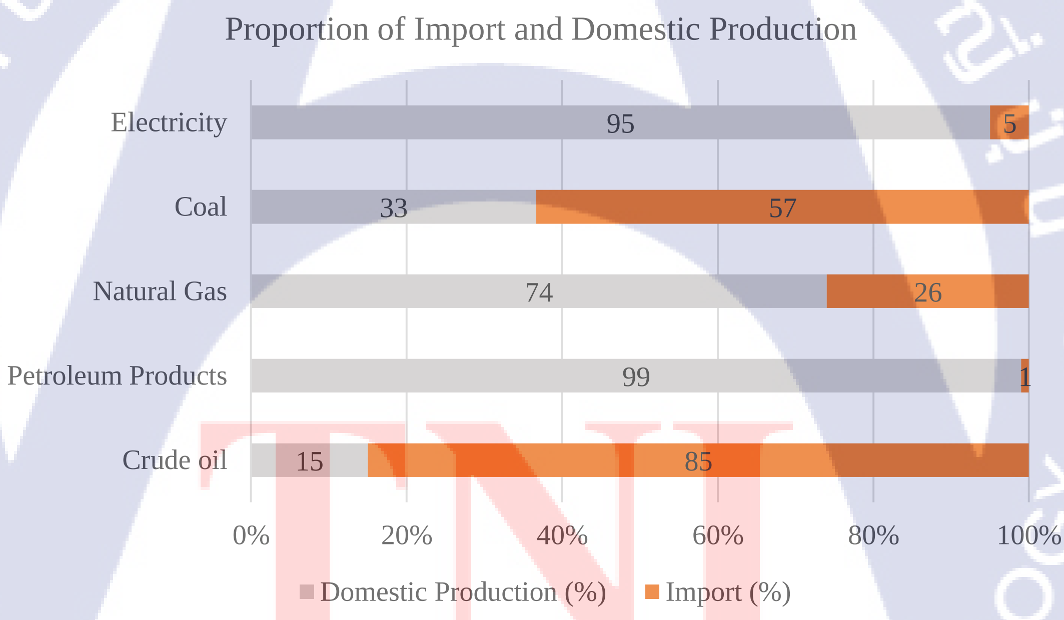


Fig.1 Proportion of import and domestic production in 2011 [1]

According the Alternative Energy Development Plan (AEDP 2012-2021), renewable energy is playing an important role, and will be developed as major energy for Thailand in the future since they will be used up to 25 percent of total energy consumption in next 10 years. AEDP is also becoming an initial step into low carbon society using renewable energy instead of fossil fuels which cause greenhouse gases (GHGs) emission. Renewable energy can come from several natural energy resources such as solar, wind, tidal, food wastes and agricultural products. Among these, biomass and biogas will share a large contribution as the inherent potential of Thailand as agricultural country. The important of biomass and biogas to Thailand's future power generation is clearly observed from the fact that the Ministry of Energy (MOE) has modified the AEDP plan to increase the potential of biomass and biogas to 4800 MW and 3600 MW, respectively (see table 1.1). According the 3000 MW of biogas based power generation is expected to be from Napier grass [2]. The new target of 3000 MW comes from Napier grass which approximately 14% of total productivity in this plan.

Napier grass or *Pennisetum purpureum Schum* in the scientific name is originated in South Africa and was first imported to Thailand in 1929. The Napier grass is a tall perennial grass which is highly resistant, easily planted and grow. The target area of Napier grass plantation should be non-irrigated area, irrigated area and low rice production area. The three main species of Napier grass, which is usually plant in Thailand, are Napier grass (*Pennisetum purpureum*), King grass (*Pennisetum purpureum CV. King grass*) and Mott Dwarf Elephant grass (*Pennisetum purpureum CV. Mott*). To serve enormous target for power generation, the Department of Livestock Development of Thailand has been developed a new species, namely Napier grass CV. Pak Chong 1, which is a combination of pearl millet grass (*Pennisetum americanum*) and king grass (*Pennisetum purpureum CV. King grass*). Napier grass CV. Pak Chong 1 has the potential in high nutrient for animal and high yields which more than the other grass. Biogas from Napier grass are planned to be utilized in 3 categories which are electricity generation, compress biogas (CBG) production for transportation and LPG replacement [3]. To serve the target of 3000 MW of renewable energy plan based on the energy ministry of Thailand [2], the massive area of 480,000 ha needs to be planted.

Therefore, land management before plantation are important. There are several methods for land planning. The Food and Agriculture Organization of the United Nation (FAO framework, 1833) [4] is a one of the famous method to find a land suitability [4]. From FAO method, it can indicate a suitability of land into 4 categories which are highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N). The other method for yield prediction, based on land geographical factor of each crop, is a statistical method namely regression model. To combine those methods to the ground-based data, GIS (Geo Information System) is the one technique that plays an important role which can use for identify suitable location for plantation.

This work aims to evaluate the potential of Napier grass plantation and to classify a suitable area by using GIS data integrating with statistical method.

Table 1.1 Alternative Energy Development Plan (2012-2021) [2]

Type of energy source	**Target (MW)**		**CF**	**Energy (Million units)**		**KTOE**	
	Old	**New**		**Old**	**New**	**Old**	**New**
1. Wind energy	1200	1800	0.15	1576.80	2365.20	134.36	201.54
2. Solar energy	2000	3000	0.15	2628.00	3942.00	223.93	334.9
3. Hydro energy	324	324	0.35	993.38	993.38	84.65	84.65
Pump storage	1284	1284	0.7	7873.49	7873.49	670.90	670.90
4. Biomass	3630	4800	0.6	22259.16	29433.6	1896.70	2508.04
5. Biogas	600	600	0.6	3153.6	3153.6	268.72	268.72
Napier grass	-	3000	0.8	2102.40	2102.40	-	1791.46
6. Municipal Solid Waste	160	400	0.6	2102.40	2102.40	71.66	179.15
7. New energy	3	3	0.4	10.51	10.51	0.90	0.90
Total	9201	13927		39335.90	63024.70	3351.81	5370.33

1.2 Objectives

1.2.1 To evaluate potential of Napier grass yields in Thailand under some criteria

1.2.2 To find a suitable area for Napier grass plantation in Thailand

1.3 Scopes

1.3.1 Study the potential of Napier grass plantation in Thailand by using ArcMap 10.0

1.3.2 Predict the Napier grass yields based on land geographical factors

1.4 Expected outcomes

1.4.1 Predict maximum potential of the Napier grass in different condition of land in Thailand

1.4.2 Suggest suitable areas for Napier grass plantation

1.5 Research plan

Table 1.2 Research Plan

Research Methodology	**2014**								**2015**		
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
1. Literature study	■	■									
2. Map model development		■	■	■	■	■					
3. Land suitability investigation				■	■	■	■				
4. Potential evaluation					■	■	■	■			
5. Result analysis								■	■	■	
6. Conclusion										■	■
7. Research publication											■

Chapter 2
Literature study

In this work, the theory of Napier grass and Geographic Information System and several academic literatures, which have been studied, will be discussed as follows;

2.1. Theory
- 2.1.1. Napier grass
- 2.1.2. Land evaluation
- 2.1.3. Multiple Regression Analysis (MRA)
- 2.1.4. Geographic Information System (GIS)

2.2. Previous study
- 2.2.1. FAO framework classification
- 2.2.2. Multiple regression model

2.3. Related Research

In the first section, the background of Napier grass will be shown. The theory and advantages of land evaluation and multiple regression will be discussed in the section 2.1.2 and 2.1.3, respectively. The theory of Geographic Information System (GIS) will be shown in section 2.1.4. The previous studies which include the FAO framework classification and multiple regression model for Napier grass plantation will be discussed in section 2.2. In section 2.3, an application of GIS and the research used the GIS integrating with statistical method and FAO framework will be discussed.

2.1 Theory

2.1.1 Napier grass

Napier grass or *Pennisetum purpureum* (also known as elephant grass) is, originally from South Africa, widely planted in South America, Puerto Rico and Philippine Island. Napier grass was first imported to Thailand in 1929 to be an animal food [5]. The main three varieties of Napier grass which mostly plant in Thailand were Napier grass (Pennisetum purpureum), King Grass (Pennisetum purpureum CV. King grass), and Mott Dwarf Elephant grass (Pennisetum purpureum CV. Mott). As it has merits both as animal food and energy resource, several provinces throughout Thailand have a pilot site for Napier grass plantation to investigate the factors which affect the growth of Napier grass.

Fig. 2.1 Napier grass CV. Pak Chong 1 [5]

According to AEDP plan, Napier grass CV. Pak Chong 1 (Fig. 2.1) was interested in the Thailand ministry of energy to be an energy crop. It is a combination of pearl millet grass (*Pennisetum americanum*) and king grass. Napier grass CV. Pak Chong 1 is a tall perennial grass which can be reached five meters, grown even in a drought area, and widely grown in tropic and subtropic. However, it cannot resist flooding. It is well-grown on land at which suitable precipitation is around 1300-1500 mm/year. Moreover, it can be planted in any type of soil texture at any region in Thailand [3,6]. From the department of livestock development, Napier grass CV. Pak Chong 1 has high nutrient for animal. It is promising a high yield production rate of 430-500 tons/ha/year, which is more than other Napier grasses and moreover, it has more ability to produce methane than other energy crops, which are used for a biogas production as shown in Table 2.1. Since the studied

To achieve the target plan of 3000 MW, 480,000 ha is needed for Napier grass plantation. Therefore, the land evaluation guideline namely FAO framework, which is a method for investigating the land suitability, multiple regression analysis and

Geographic Information System (GIS) have been studied and discussed in the section below.

Table 2.1 Methane production ability of biomass crop

Types of biomass	**Ability to produce methane (m^3CH_4/kg)**
Corn	0.378
Rice straw	0.372
Sugar cane leaves	0.313
Corn Stalk	0.2 (±0.03)
Cassava	0.23 (±0.04)
Napier grass	0.617

2.1.2 Land evaluation

The land use planning is a guideline for making a decision of which area should be used to gain the most benefit in environmental resources management. Land evaluation is defined as the assessment of land performance for a specific purpose involving the basic survey and the studies of land form, soil and other land factors [7]. To be the most value in planning, the range of land used has to be limited in order to land economic and social context of the area were considered.

2.1.2.1 FAO framework

The framework for land evaluation was published in 1976, also known as FAO framework (the Food and Agriculture Organization of the United Nation), which is a methodological approach for identifying the suitability of agricultural land use. FAO framework is a qualitative land suitability classification which can define the suitability for plantation. The frameworks for specific major land use and crop were published, which based on the original framework in 1976, namely rain-fed agriculture, irrigated agriculture, livestock and forestry production in 1983, 1984, 1985 and 1991, respectively.

Thailand also uses such a framework to investigate the suitability for plantation. The framework which is suitable for Thailand's agriculture is the FAO framework for rain-fed agriculture in 1983. It was used to study soil which effects on the growth of plants. However, there is still a difference between land characteristics in Thailand and the country which can make an unreliable result. Thus, to use this method, analyzed factors should be based on a real ground data of Thailand.

Land suitability was classed into 2 orders which is S order, which referred to suitability, and N order which referred to Not-Suitability. Moreover, 2 orders are divided and scored into 4 classifications which are shown in Table. 2.2.

Table 2.2 Suitability classification

Classifications	**Score**	**Definition**
S1 (Highly Suitable)	1.0	Land which has no significant limitation to sustain an application of a given use, or only has a minor limitation which no significant reduce productivity or benefits.
S2 (Moderately Suitable)	0.8	Land have a limitation which is in moderately severe of a given use. The limitation will reduce the productivity or benefits.
S3 (Marginally Suitable)	0.4	Land have a limitation which is in severe of a given use and will reduce the productivity or benefits.
N (Not suitable)	0.1	Land have a limitation which cannot be currently used in this time.

Thereafter, all factors will be multiplied by using the score mentioned above and will be called overall suitability. The score which gets from each factor will be rearranged and classified into land suitability. The new score range will be shown in Table. 2.3, upper limit and lower limit score will be rearranged depending on number of affected factors on crop growth.

Table 2.3 New overall suitability score arrangement

Class	New score range classified		Land Suitability Class
	Lower limit	Upper limit	
S1	(0.8^n)	(1^n)	Highly Suitable
S2	(0.4^n)	(0.8^n)	Moderately Suitable
S2	(0.1^n)	(0.4^n)	Marginally Suitable
N	$< (0.1^n)$		Not suitable

Where n is the number of affected factors on crop growth.

From the advantage-disadvantage of FAO framework table 2.4, it can be concluded that FAO framework can only show qualitative results which cannot describe the relation between each factors. Therefore, to study the relationship between each factors and crop dry matter yield, the multiple regression analysis, which is a statistical method, has been studied in the section of 2.1.3.

Table 2.4 The advantage-disadvantage of FAO framework

Advantage	Disadvantage
• Land suitability classification can be a prior data for land use decision • The result of land suitability classification can be a guideline to improve land quality.	• FAO framework is just a broad guideline for land evaluating which the user should be a decision maker • The framework can only show qualitative results.

2.1.3 Multiple Regression Analysis (MRA) [8] [9]

Multiple regression is a statistical technique that allows to predict more than two independent factors which have an effect on the dependent variable. A predict values of a dependent variable, Y, give a set of p of an independent variable (X_1, X_2, X_3… X_p).

In Multiple Regression Analysis, the relationship between dependent and independent variable is presented by the following equation.

$$Y = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \ldots + \beta_p X_{pi} \quad (2.1)$$

Where,

Y	=	the dependent variable
X_i	=	the independent variable
β	=	the constant

β_1 to β_p are the coefficients which related to the set of p variables. Multiple regression can be thought of a simple linear regression where p =1. The term of ‘linear’ is used because in multiple regression is assumed that Y is directly related to linear combination of the set of p variable. The multiple regression does not allow to make casual inferences, but does allow to investigate the association between independent and interested dependent variable.

Thus, FAO framework and multiple regression analysis are the methods which can be shown in qualitative and quantitative result, respectively. To identify the suitable area and to estimate the dry matter yield which can get from each land, Geographic Information System (GIS) has been studied to identify studied land in section 2.1.4.

2.1.4 GIS (Geographic Information System)

The main method of representing and identifying the location of geographic on landscape is a map which is composed of different geographic features [10]. A geographic information system (GIS) [11] is a computer-based system which can store, collect and analyze spatial data. GIS data represents an information, called spatial data, display data which related to positions on the Earth's surface and man-made feature and can show many different kinds of data in one map. It references the real world spatial data to a coordinate system and its features can be separated into different layers. A

GIS system can store an information in each category called layer. A layer can present a lot of information such as street, land used, river drainage and flood plains (Fig 2.2).

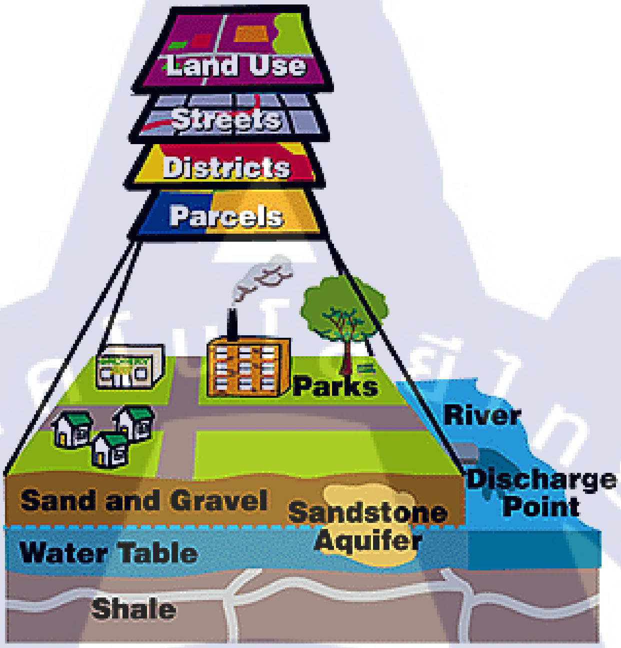


Fig. 2.2 Integration of map [10]

A GIS can also store an attribute data which is used to describe an information of map feature. An attribute data is placed in a database which separates from graphic data, but it is linked together. Therefore, a GIS can combine geographic and the other data to generate maps and reports. Furthermore, a GIS can also enable users to collect and manage location-based information.

The general sources of spatial data are from the hard copy map, remote sensing images, point data from surveys and digital data files. The spatial data are usually in an analog form and needs to be conversed to digital form. Attribute data also have a variety of data sources, which are in the form of texts and tabular data, and usually input by manual keying. (Fig. 2.3)

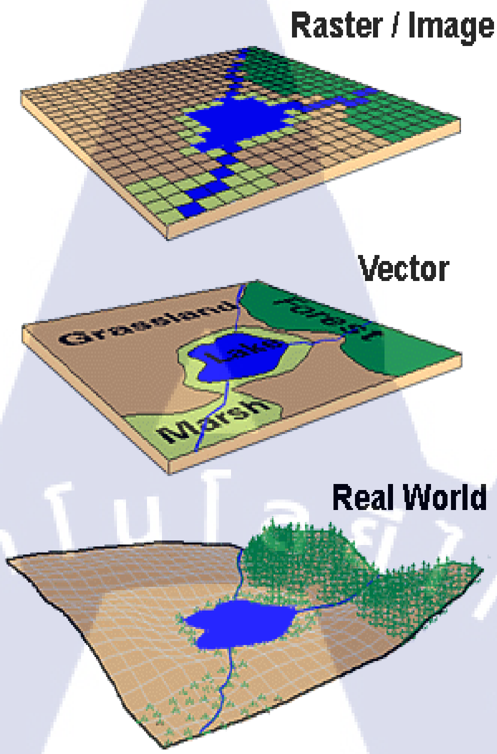


Fig. 2.3 Data integration [11]

With GIS technology, researchers can also use the data to study topics of any different fields of work. Many businesses used GIS technology to determine where to locate their new store. Moreover, GIS also be used in agriculture and soil, which data include information on the country's land resources including soils, climate, cropping system and crop suitability. Updated maps are much easier by using GIS technology and simply be added to the existing GIS program. In this program, the new map will be shown on screen. This technology skips the traditional process of drawing a map which is a time consuming and expensive process. Therefore, there are many softwares which use in this field of work such as ArcGIS software, which is a system for geographic data creation, integration, management and analysis, and AutoCAD Map software which has a special tool to create and produce maps and geographic information.

2.2 Previous studies

2.1.2 The properties of affected parameters of Napier grass growth

Since Napier grass was interested by MoE to be an energy resource. There were several researches, which studied factors affected the growth of Napier grass, published by animal nutrition research and development center during 1993-2005 [12]-[20]. The studied data of those researches were obtained from 9 reports of 7 pilot plants of livestock development department all around Thailand, except the Southern region. The pilot plants are located in Lampang, Nakhon Panom, Petchabun, Sukhothai, Chainat, Sa Kaeo and Petchaburi province as depicted in Fig. 2.4.

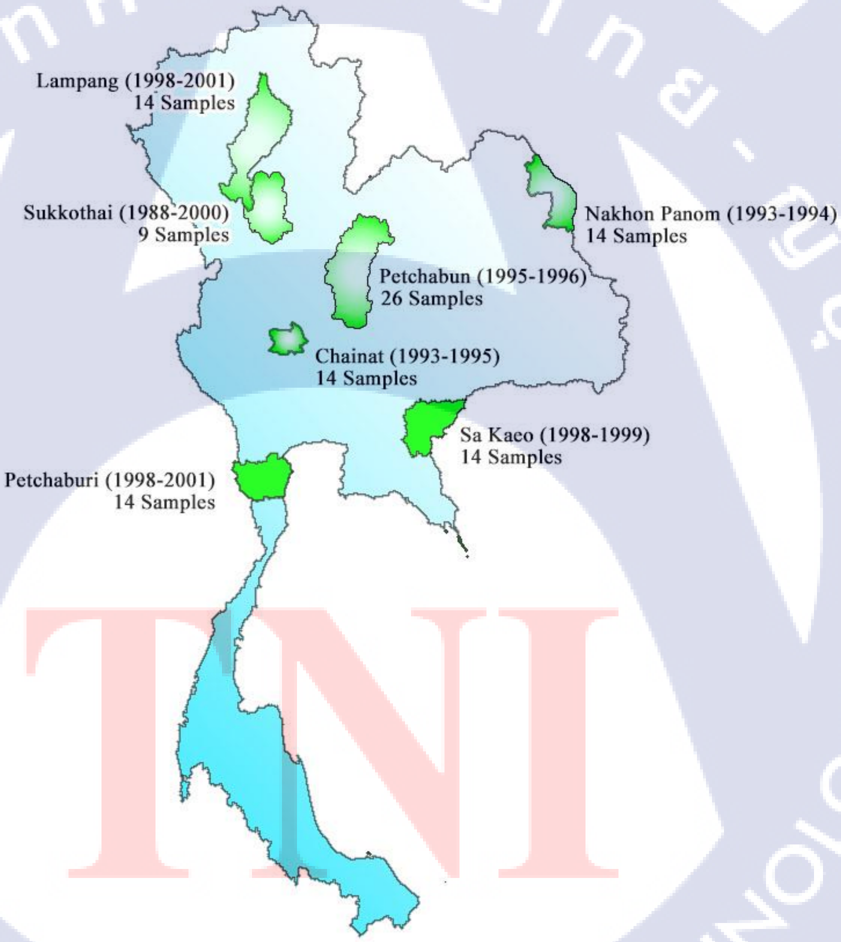


Fig. 2.4 The location of pilot plant of Napier grass plantation in Thailand

From the studied report, it was found that there are 2 main groups of factor that effect to the growth of the plant which are geographical factors and man-made factors. However, by considering from the economic viewpoint, the geographical factors are more important than the man-made factors. Therefore, the geographical factors can be defined into 2 groups which are soil properties and water supply as shown in Table 2.5.

Table 2.5 The affected parameter for Napier grass plantation

Groups	**Parameters**
Soil properties	1. Soil texture
	2. Soil fertility
	3. Soil drainage
	4. pH
Water supply	5. Precipitation

To give a better understanding and analyze more easily in the effect parameter, each parameter will be grouped and scored.

2.2.1.1 Soil texture

Soil texture was defined into 3 groups by the United States Department of Agriculture (USDA) [7] which are 1. Clay soil, which has soil texture less than 0.002 mm, 2. Silt soil, which is a soil with a diameter of 0.002-0.02 mm, and 3. Sandy soil, which is a soil with a diameter range of 0.02-2.00 mm. Therefore, they can be divided into 12 classes of soil by each soil proportion as shown in Fig. 2.5. The score of each soil texture were ranked as shown in Table 2.6.

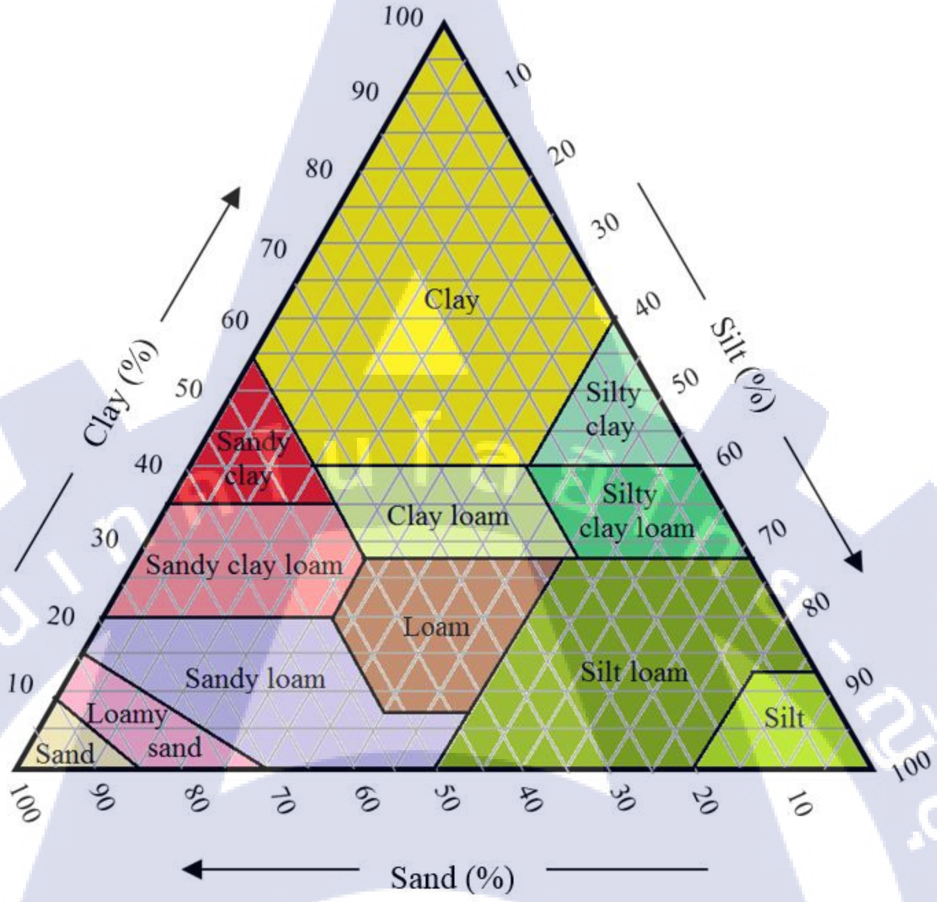


Fig. 2.5 The proportion of each type of soil

Table 2.6 The score of soil texture by its type of soil

Main soil	Soil texture	Soil type	Score
Clay	Smooth	Clay, Sandy clay, Sandy clay loam	1
Silt	Somewhat smooth	Clay loam, Silty clay, Silty clay loam	2
	Medium smooth	Silt, Silt loam, Loam	3
	Somewhat rough	Sandy loam	4
Sand	Rough	Sand, Loamy sand	5

2.2.1.2 Soil fertility

Soil fertility is an ability of soil to contain the nutrient for the growth of plants. The Land development department defined the soil fertility by the chemistry of soil, i.e. proton exchangeability and the amount of useful Potassium and Phosphorus in soil. The soil fertility was divided into more than 13 classes. However, soil fertility classification was grouped into 3 ranks as shown in Table 2.7.

Table 2.7 The rank of soil fertility

Order	Definition	Soil fertility classification
1	Low	<7
2	Medium	8-12
3	High	>13

2.2.1.3 Soil drainage

Soil drainage is a one of the factors which is affected to the growth of the plant. When soil retains too much water or restrict of water, the root of the plant can get suffocation, disease or death. Soil drainage was divided into 7 classess according to soil survey report [21] as displayed in Table. 2.8.

Table 2.8 Soil drainage classification

Order	Soil drainage classification
1	Very poorly drained soil
2	Poorly drained soil
3	Somewhat poorly drained soil
4	Moderately well drained soil
5	Well drain soil
6	Somewhat excessively to excessively drained soil
7	Excessively drained soil

2.2.1.4 pH

pH is the logarithmic scale of 1-14 which is shown the level of acidity, neutral and alkalinity. The solution with the pH less than 7 is acidic and greater than 7 is alkaline. The range of soil pH will be as depicted in Table 2.9.

Table 2.9 The range of soil pH

pH	**Definition**
1-3.5	Ultra acid
3.5-4.4	Extremely acid
4.5-5.0	Very strongly acid
5.1-5.5	Strongly acid
5.6-6.0	Moderately acid
6.1-6.5	Slightly acid
6.6-7.3	Neutral
7.4-7.8	Slightly alkaline
7.9-8.4	Moderately alkaline
8.5-9.0	Strongly alkaline
9.0-14	Very strongly alkaline

2.2.1.5 Precipitation

Precipitation is a water which released to the ground in the form of rain, freezing rain or snow. It is the primary connection which is provided for the delivery of the earth's water. For the crop plantation, precipitation is a water supply for crop growth. In Thailand, most of the precipitation is in a form of rainfall, which is measured in a accumulated unit of mm/year.

Land development department [22] has defined Thailand's soil into 62 groups, each group contained soil characteristics and soil properties which are soil texture, soil fertility, soil drainage and pH as shown in Table 2.10.

Table 2.10 Soil group and their properties

No. of Soil group	Soil texture	Soil drainage	Soil fertility	pH
1	C and SiC	Poorly drained soil to Somewhat poorly drained soil	Medium	6.75
2	C and SiC	Poorly drained soil	Medium	5
3	C and SiC	Poorly drained soil	Medium	6.75
4	LS and C	Poorly drained soil to Somewhat poorly drained soil	Medium	7.25
5	CL and LS	Poorly drained soil	Medium	7.25
6	LS	Poorly drained soil	Low	5
7	CL	Poorly drained soil to Somewhat poorly drained soil	High	7.5
8	C	Poorly drained soil	Medium	7.75
9	C	Poorly drained soil	Medium	4.75
10	C	Poorly drained soil	Medium	3.75
11	C	Poorly drained soil	Medium	4.5
12	C	Very poorly drained soil	High	8
13	SiCL and CL	Very poorly drained soil	High	7.5
14	C and CL	Very poorly drained soil	Low	4.25
15	LS and SCL	Very poorly drained soil	Medium	7.25
16	LS and SCL	Poorly drained soil	Low	5
17	SL	Poorly drained soil to Somewhat poorly drained soil	Medium	5.25
18	SL	Poorly drained soil to Somewhat poorly drained soil	Low	6.25
19	LS or SL	Poorly drained soil to Somewhat poorly drained soil	Low	7.5
20	SL	Poorly drained soil to Somewhat poorly drained soil	Medium	8

Table 2.10 Soil group and their properties (continued)

No. of Soil group	Soil texture	Soil drainage	Soil fertility	pH
21	L and SL	Moderately well drained soil	Low	5.75
22	SL	Poorly drained soil to Somewhat poorly drained soil	Low	6.5
23	LS or SL	Poorly drained soil	Medium	7.5
24	S or SL	Poorly drained soil to Moderately well drained soil	Low	6
25	L or LS	Poorly drained soil to Somewhat poorly drained soil	Low	5
26	LC	Well drain soil	Medium	5.5
27	LS	Well drain soil	Medium	5.75
28	C	Moderately well drained soil	High	7.5
29	SiC or C	Well drain soil	Medium	5.5
30	SCL	Well drain soil	Medium	6
31	LS	Poorly drained soil to Somewhat poorly drained soil	Medium	6
32	LS	Well drain soil	Medium	5
33	LS	Moderately well drained soil	Medium	7.25
34	SL	Well drain soil	Low	4.75
35	SL	Moderately well drained soil	Low	5
36	SL	Well drain soil	Medium	7
37	SL or LS	Moderately well drained soil	Low	6
38	SL	Well drain soil	Medium	3.25
39	SL	Well drain soil	Low	5.25
40	SL	Well drain soil	Low	5.75
41	SL	Moderately well drained soil	Low	7.25
42	SL	Excessively drained soil	Low	5.25

Table 2.10 Soil group and their properties (continued)

No. of Soil group	Soil texture	Soil drainage	Soil fertility	pH
43	SL	Somewhat excessively to excessively drained soil	Low	6.75
44	S or SL	Somewhat excessively to excessively drained soil	Low	5.75
45	LS or LC	Well drain soil	Medium	5
46	LC	Well drain soil	Low	5
47	LC or C	Moderately well drained soil	Medium	5.75
52	SL	Well drain soil	High	7.75
53	CL	Well drain soil	Medium	5.5
54	CL or C	Well drain soil	High	7.5
55	SiCL	Moderately well drained soil	Medium	7
56	SL	Well drain soil	Low to medium	5
57	-	Very poorly drained soil	High	5
58	-	Very poorly drained soil	High	4.25
59	-	Poorly drained soil to Somewhat poorly drained soil	Medium	-
60	-	Moderately well drained soil	Medium	-
61	-	-	-	-
62	-	Moderately well drained soil	-	-

Where in soil texture column, the abbreviations of C, Si, L and S are referred to clay, silt, loam and sand, respectively. From the studied report, the factors were classified into the each rank in the next sections.

From this model, the rank of input parameters was input directly as shown in the above classification. The pH scale was in the range of 1-14, soil drainage was divided into 7 classes, precipitation was input directly in the unit of mm/year, and the last parameter, soil fertility was defined into 3 classes which are low, medium and high.

2.2.2 FAO framework classification

From previous work of our laboratory, Phianchurat [23] was rearranging each parameter into a suitability order of S1, S2, S3 and N. The classification of FAO framework was classified based on Napier grass pilot plantation report. The classification of Napier grass plantation factors is shown in Table 2.8.

As seen in table 1, the suitable class were classified into 4 levels, which were highly suitable (S1), moderately suitable (S2), and marginally suitable (S3) and not suitable (N). The scale classification was based on previous reports and handbook for Napier grass CV. Pak Chong 1 plantation [3]. According to the handbook, the best condition of soil texture, soil fertility, soil drainage and amount of precipitation for Napier grass plantation was known. The highly suitability classification of soil texture should be a combination of silt and sand soil. Since the large particle soil was good at drainage, the well-drained soil is becoming a classification of highly suitability for this plant. However, excessively drained soil is not good for any plant since soil cannot contain nutrients for the growth of plant, thus, this ability of drainage is in a the not suitable class for Napier grass. For soil fertility classification, Napier grass can grow well at high soil fertility. Therefore, the classification for suitable range of S1, S2 and S3 are high, medium and low fertility, respectively. The suitable range of precipitation for Napier grass is 1000-1500 mm/year based on handbook, thus the other range of precipitation will be at the class of S2 and S3. Nevertheless, the amount precipitation of lower than 600 and higher than 2000 mm/year are in the not suitable class since they was not a usual range for Thailand's annual precipitation. For the last parameter of soil pH, the study of Napier grass plantation was only in the range of 5-8 and it was found that Napier grass was well grown at neutral to slightly alkalinity soil [24]. Therefore, the highly suitability class for soil pH was at 7-8 and beyond the study range of soil pH was in not suitable classification.

Table 2.11 The classification of affected factors by FAO framework

Parameters			**Suitability level and score**			
Group	**Factors**	**Unit**	**S1 (1)**	**S2 (0.8)**	**S3 (0.4)**	**N (0.1)**
1.1 Soil texture	Soil texture	-	L, SL, Si, SiL,S,LS	CL, SCL, SiCL	SC, C, SiC	C-LA
1.2 Soil fertility	Soil fertility	-	High	Medium	Low	-
1.3 Nutrient availability	pH	-	7.4-8.4	6.6-7.3	5.6-6.5	<5.5 >8.5
1.4 Oxygen availability	Soil drainage	-	5,6	3,4	1,2	7
1.5 Water supply	Precipitation	mm.	>1000 <1500	700-1000 1500-1800	500-700 1800-2000	<500 >2000

2.2.3 Multiple regression model

In this section, the multiple regression model is also got from Phianchurat [24]. This model is in a 95% at the confidence level and 70.4% of adjusted R^2. The model shows the relationship between affected factors to the Napier grass plantation growth and dry matter yield. The multiple regression analysis is shown in eq. 2.2. After an analysis by using the stepwise method in SPSS software, affected factors are remained only 4 factors which are pH, soil drainage, precipitation and soil fertility. The soil texture factor has no influence to the Napier grass yield.

$$DMY = 6.241(pH) - 3.692(DN) - 0.002(PC) + 3.199(SF) - 7.655 \quad (2.2)$$

Where,

DMY = the dry matter yield (tons/ha/year)

DN = the soil drainage

PC = the precipitation (mm/year)

SF = the soil fertility

Table 2.12 Regression Model of Napier grass plantation behaviour

Parameters	Coefficient			Significant
	Unstandardized		Standardized	
	B	S.E.	Beta	
Constant	-7.655	3.188	0	.018
Soil Fertility (SF)	3.199	.531	.353	.000
Soil Drainage (DN)	-3.692	.356	-.768	.000
pH	6.241	.578	.816	.000
Precipitation (PC)	-.002	.001	-.135	.021

From the standardize beta coefficient of table 2.12, it was found that soil fertility and soil pH had a positive relation to dry matter yield, on the other hand, water supply factors which are soil drainage and precipitation were found in the negative relation. However, the model is a linear model which it can predict accurately in some range of data for example the soil pH should be in the range of 5-8 which can give the most reliable result.

From this model (eq. 2.2), the rank of input parameters was input directly as shown in the above classification. The pH scale was in the range of 1-14, soil drainage was divided into 7 classes, precipitation was input directly in the unit of mm/year, and the last parameter, soil fertility was defined into 3 classes which are low, medium and high.

2.3 Related research

GIS was applied to evaluate land suitability and crop yield prediction. LI Bo et al. [25] developed land ecological suitability evaluation (LESE) and grey relational analysis (GRA) which is combined with AHP to evaluate the land suitability. The model was analyzed by using GIS method to evaluate the suitability of tea crops, one of the most valuable cash crops in southern China, in Zhejiang Province. The result was shown in highly, moderately, and non-suitable regions for the cultivation of tea crops in Zhejiang Province. The combination of modified LESE model and GIS could be useful in quickly and accurately evaluating the land suitability of tea crops, providing a scientific basis for the rational distribution of tea crops and acting as a reference to land policy makers and land use planners.

Applied of statistical method and GIS are being used for crop yield estimation, landslide analysis, land use efficiently management and etc. GIS and Analysis Hierarchy Process (AHP), one of the statistical methods, used for site suitability evaluating for ecotourism in Surat Thani Province, Thailand. Bunruamkaewa and Murayama [26] evaluated ecotourism site based on nine chosen criteria including visibility, land use, reservation, species diversity, elevation, slope, proximity to cultural sites, distance from roads and settlement size. Those factors were selected according to the professional expert's opinions. It was found that this methodology was useful to identify ecotourism sites by linking the criteria deemed important with the actual resources of the Province.

Agriculture is one of the oldest economic practice of human civilization. There are many studies in applying GIS to estimate crop yields. Early prediction of crop yield is important for planning and taking policy decisions. Many countries use this conventional technique of yield estimation based on ground based visits and reports. Satellite data are being used for crop monitoring and yield estimation. In India, wheat is one of the most important food grains. Production of wheat in India is about 70 million tonnes per year and becoming the second largest producer in the world. Goswami et al. [27] used remote sensing and GIS to estimate wheat crop acreage of Indore district. The image of the study area and map data were used to analyze.

FAO framework is also popular in using with GIS, which FAO is a framework or guideline for land evaluation. Soil mapping in Denmark has a long history, soil map based on conventional mapping approaches have been produced and a fine resolution of soil map of the whole country is needed. Adhikari et al. [28] developed map by using soil-landscape models generated with a decision tree based digital soil mapping technique. Input data were geology, land use and area of wetlands. After validation of predicted map, validated by point validation and map to map comparison, confirmed that the output is reliable. Akinchi et al. [29] was also investigating land use for agricultural use in Yuseferi district of Artvin city in Turkey, suitability by integrating

GIS and FAO framework together and ranking the suitability method by using AHP technique. The authors use data of soil group, land use, soil dept and erosion to analyze. The chosen area for this study is avoided forest land. The result of this study was shown in qualitative results of each area in a suitability scale of S1, S2, S3 and N. The suitable area is 13.5% of the total area of this district which the most suitable area is S3 and N in the relative proportional of 51.2% and 27.4%, respectively.

Mongkolsawat and Putklang [30] evaluated the land suitability for rubber plantation in Northeast, Thailand. Rubber is an economic crop which has the highest net income. The result in the expansion of the rubber plantation area was from South to Northeast. The land suitability evaluation, based on FAO framework, was conducted by overlaying analysis of land. The analysis factors are water availability, oxygen availability, nutrient availability index, rooting condition and topography, and calculated by land suitability equation (see equation 2.3). The overlay operation (Fig 2.6) on the layer provided the suitability of the land. The result was classified by highly, moderately, marginally and not suitable area. The result from this study can be used to support the identification of a sustainable expansion area.

$$\text{Land suitability} = W*O*N*I*R*G \tag{2.3}$$

Where,

W = the score for water availability for plant

O = the score for oxygen availability for plant

N = the score for nutrient availability for plant

I = the score for water retention of soil

R = the score for root condition

O = the score for land topography

Sinthuvanich [31] used the overlay process to land use plan for efficient agriculture in Wang Nam Khiew, Nakornratchasima province. The factors affecting land use were collected, including soil characteristic, topography, climate and water resource. The suitable area for economic crop will be analyzed based on spatial analysis technique. The recommended agriculture crop are rice, sugar cane and tapioca plantations for the rain agriculture zone. For irrigated agriculture zone, rice, orange, lychee and sweet tamarind were recommended.

Intarong [32] analyze the appropriate area for conservation of sangyod rice in Pattalung province. The factors affecting sangyod rice were used, including slope, soil drainage, soil nutrients, soil reaction, soil texture, soil depth and salinity. Overlay technique was used under GIS process. The result indicated four categories which are most suitable, moderated, low suitable and unsuitable area.

Sawasawa [33] predicted crop yield in India by using remote sensing, space-borne satellite based NDVI, and GIS. Management and land factor were used for yield prediction at field level. Moreover, stepwise linear regression was used to related yield to the management and land factors. The result was shown in a quantity which can define the yield estimation model.

However, using GIS with FAO framework alone can only find a suitable area for plantation, but fails to predict the dry matter yield. Therefore, to achieve both suitable area and dry matter yield, using GIS integrating with multiple regression analysis and FAO framework has been proposed in this work

The key findings of the related research mentioned above are summarized in Table 2.12. The details of the research methodology of this research are presented in chapter 3.

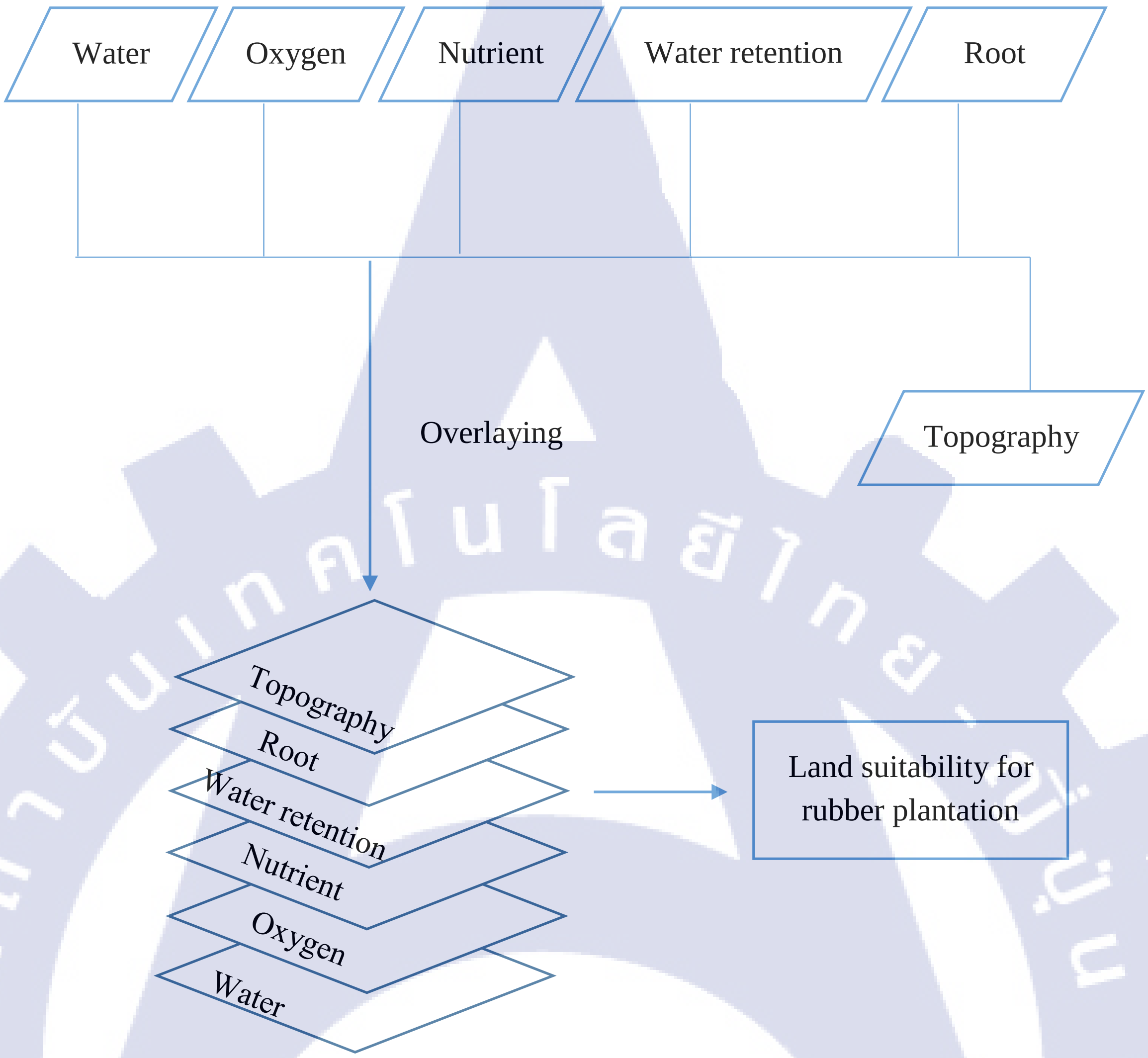


Fig 2.6 Overlaying process

Table 2.13 Summary of literature study

Researcher groups	Year	Study	Results
Goswami S. B. et al. [27]	2012	Remote sensing and GIS were used to estimate wheat crop acreage of Indore district. The image of the study area and map data were used to analyze.	Wheat acreage estimation has been done, the result found that deviated from the Land record Commissioner LRC by +19.
Adhikari et al. [28]	2013	The development of map by using soil-landscape models generated with a decision tree based digital soil mapping technique.	After validation of predicted map, validated by point validation and map to map comparison, confirmed that the output is reliable.
Akinchi, Ozalp and Turgut [29]	2013	Land use for agricultural use in Yuseferi district of Artvin city in Turkey were investigated suitability by integrating GIS and FAO framework together and ranking the suitability method by using AHP technique	The result of this study was shown in qualitative results of each area in a suitability scale of S1, S2, S3 and N
Mongkolsawat and Putklang [30]	2010	• The land suitability for rubber plantation in Northeast, Thailand were evaluated. • The analysis factors are water availability, oxygen availability, nutrient availability index, rooting condition and topography, and calculated by land suitability equation	

Table 2.13 Summary of literature study (Continued)

Researcher groups	Year	Study	Results
Intarong [32]	2007	The plan of using the agricultural land has been done. The overlay process were used to land use plan for efficient agriculture in Wang Nam Khiew, Nakornratchasima province	The land use management process can be suggest for the agricultural propose.
Sawasawa [33]	2003	• Crop yield in India were predicted by using remote sensing, space-borne satellite based NDVI, and GIS • Stepwise linear regression was used to related yield to the management and land factors.	The predicted yield model was obtained

Chapter 3
Research Methodology

This chapter presents a research methodology which is described in the flow diagram in Fig. 3.1.

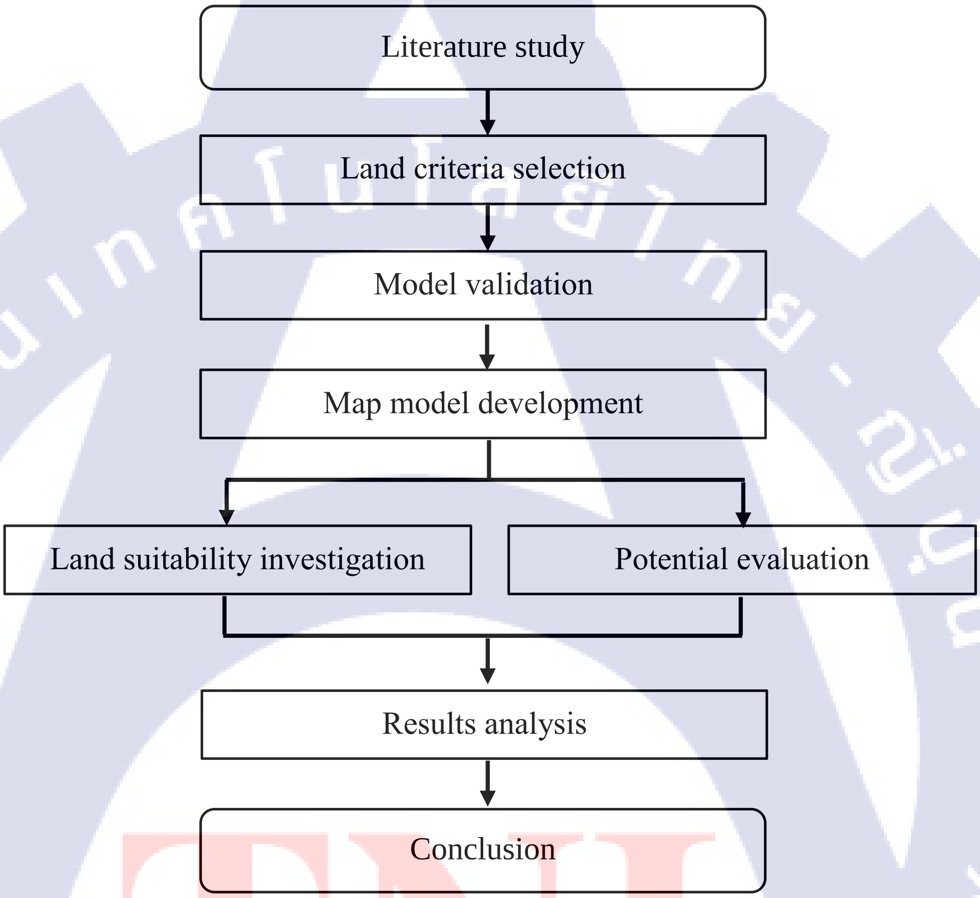


Fig. 3.1 Flow diagram of research methodology

Since the theory and previous study has been presented in the previous chapter, in this chapter, the criteria for land selection will be discussed in section 3.1. Map model development methodology will be described in section 3.2. In section 3.3 and 3.4, the investigation of land suitability and the evaluation of Napier grass potential will be described, respectively. After the land suitability and potential was known, the results will be discussed in section 3.5.

3.1 Land criteria selection

After the literature study has been done in the previous chapter, to serve an AEDP plan of the enormous area for plantation, the key for area selection in this work should be neither economic crop plant, nor forest, nor inhabited by the others. The selected area which is based on the land use report are an abandon field, an abandon farm, a pasture, a groove wood and a lower land. The area was selected by using the ArcMAP 10.0 software.

3.2 Model validation

In the map model development process, the soil properties and the precipitation data of 8 pilot plantations was obtained which is based on ArcMAP 10.0 software. The data was located by real coordinate of the department of livestock development. Thereafter, all data was compared to the real data which obtained from the studies. The comparison show the reliable of this model in both of finding a suitable area and evaluating a potential of Napier grass.

3.3 Map model development

The analyzed data was based on the model which got from Phianchurat [24]. The affected factors of Napier grass plantation are soil fertility, soil drainage, soil pH and precipitation. The maps which was used in this work are land use map, soil map and precipitation map. The obtained area selection was from the land use map. From soil map, the soil group was obtained in this process. Soil groups can be divided into 62 groups by land development department. Soil properties can be obtained from soil group which contain soil fertility, soil drainage and soil pH. The last affected factor of precipitation was obtained by precipitation map. The Thailand map was shown in Fig. 3.2 (a). To be more clarify in the used map, the example of 3 maps of land use, soil and precipitation from Phetchabun province was shown in Fig. 3.2 (b)-(d), respectively. The source and year of each map data was shown in Table 3.1.

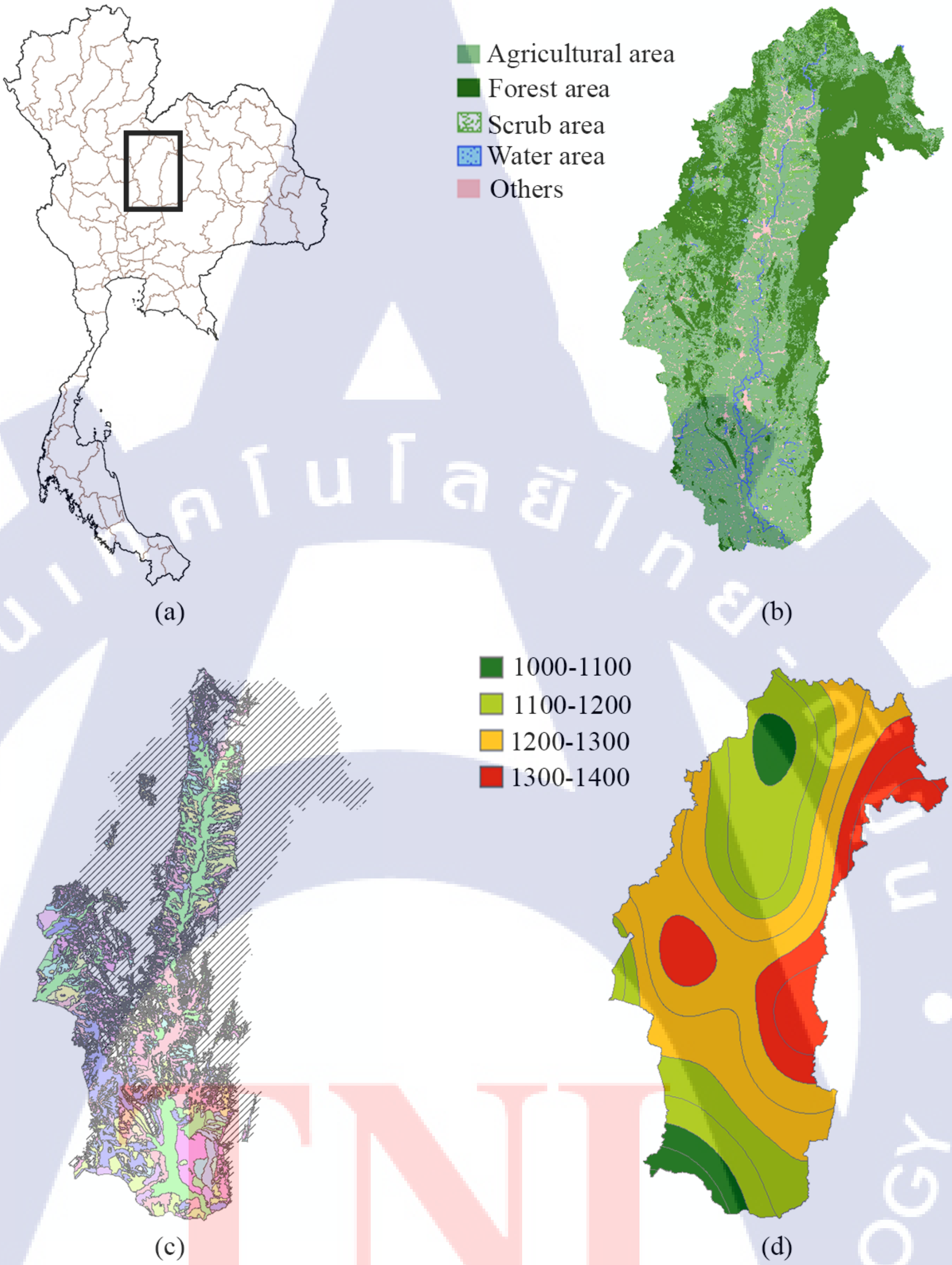


Fig. 3.2 The map of a) Thailand, b) land use, c) soil and d) precipitation (mm/year)

Table 3.1 The source of map data

Map	Scale	Year	Source
1. Land use	1:25000	2007-2011	Geo-Informatics and Space Technology Development Agency (GISTDA)
2. Soil	1:25000	2008-2013	Land development department of Thailand
3. Precipitation	1:50000	2011	Hydro and Agro Informatics Institute (HAII)

Therefore, the available area was done by overlaying process of 3 mentioned above maps which area was based on the land use map and the analyzed output data contained the data of soil properties and precipitation. The overlaid map data was exported and analyzed to investigate land suitability and estimate the Napier grass yield in section 3.3 and 3.4, respectively.

3.4 Land suitability investigation

To find land suitability for Napier grass plantation, the classification was based on the FAO framework (1983) which is classified by Phianchurat [24]. The score of 4 parameters of Napier grass plantation, which is soil fertility, soil drainage, soil pH and precipitation, was shown in Table 2.8. The overall suitability will be rearranged in Table 3.2.

Table 3.2 The rearrange of land suitability class

Class	New score range classified		New score range classified		Land Suitability Class
	Upper limit	Lower limit	Upper limit	Lower limit	
S1	(1.0^4)	(0.8^4)	1.0	0.4096	Highly Suitable
S2	(0.8^4)	(0.4^4)	0.4096	0.0256	Moderately Suitable
S2	(0.4^4)	(0.1^4)	0.0256	0.0001	Marginally Suitable
N	$< (0.1^n)$		<0.0001		Not suitable

Since the overall suitability was done, the available area will be classified into class S1, S2, S3 and N.

3.5 Potential evaluation

The evaluated potential was done by using multiple regression model which was shown in eq. 2 in chapter 2. The data of soil properties as shown in Table 2.7- 2.9 and water supply was applied in this model based on current land data from each map.

3.6 Results analysis

Since the suitable area and potential of Napier grass plantation was known by FAO framework and multiple regression analysis, respectively, the results will be presented and discussed in the results analysis section.

Chapter 4
Result and discussion

The results obtained from the geographical information analysis are presented and discussed in this chapter as follows.

4.1. Model validation
4.2. Locating the suitable area
4.3. Evaluating the potential of Napier grass yield

4.1 Model validation

Pilot plants from the studied report were located in the department of livestock development of 7 provinces, which are Lampang, Nakhon Phanom, Petchabun, Sukhothai, Chainat, Sa Kaeo and Petchaburi province. The geographic coordinate of each plant was collected as shown in table 4.1.

Table 4.1 The coordinate of the 7 pilot plants

No.	Pilot plant location	Coordinate	
		Latitude (N)	Longitude (E)
1	Lampang	18°45’16.229”	99°30’30.118”
2	Nakhon Phanom	17°22’2.898”	104°36’50.63”
3	Petchabun	16°26’31.603”	101°9’7.906”
4	Sukhothai	16°46’48.324”	99°44’9.164”
5	Chainat	15°8’35.848”	100°10’46.974”
6	Sa Kaeo	13°21’51.408”	102°16’58.357”
7	Petchaburi	12°39’10.742”	99°52’35.987”

After locating the position of the pilot plants on the soil and precipitation maps, the data were obtained as shown in table 4.2.

Table 4.2 The obtained soil properties and precipitation [12]-[20]

No.	Pilot plant location	Soil properties				Precipitation
		Texture	Drainage	Fertility	pH	
1	Lampang	Silt loam	Well drain soil	Medium	7	1150
2	Nakhon Phanom	Loam silt	Somewhat poorly drained soil	Medium	7.25	1000
3	Petchabun	Silt loam	Moderately well drained soil	Low	5	1200
4	Sukhothai	Silt clay loam	Moderately well drained soil	Medium	7	1350
5	Chainat	Loam silt	Well drain soil	Medium	5	1300
6	Sa Kaeo	Silt loam	Well drain soil	Low	5.75	1050
7	Petchaburi	Silt loam	Moderately well drained soil	Low	6	2250

Most of the data from the maps were in concurrence with the real ground data, except the precipitation data, since the precipitation data were collected in different years (reports and map). The map data of Nakhon Phanom province was the only pilot plant which its data do not coincide with the report data. This error might cause by the rough contour on the map. Thereafter, the dry matter yield was calculated by using the multiple regression model and compared to the production yield obtained from report of each pilot plant which show in Table 4.3. Since the accuracy of the predicted model was 70.4%, the error of prediction would not excess 30%. After the analysis, it was found that the errors from the predicted data and the pilot plant data were varied from 1.2-25.6%, except only the plant in Nakhon Phanom province.

Table 4.3 The comparison between the report and predicted data

No.	Pilot plant location	Dry matter yield (ton/ha)	Predicted yield (ton/ha)	%error
1	Lampang	18.89	14.26	24.5%
2	Nakhon Phanom	10.88	15.28	40.5%
3	Petchabun	13.53	16.99	25.6%
4	Sukhothai	19.87	21.94	10.4%
5	Chainat	21.40	23.11	8.0%
6	Sa Kaeo	25.85	24.96	3.4%
7	Petchaburi	11.00	10.87	1.2%
Total error				16.2%

4.2 Locating the suitable area

Based on the criteria mentioned earlier, the usable area in the land used map were an abandon field, an abandon farm, a pasture, a grassland, a groove wood and a lower land. The analyzed areas (see Fig. 4.1), including all provinces in Thailand (76 provinces based on the data before an establishing of Bueng Kan province in 2011), of this work were divided into 6 regions as follows.

1. Northern region
2. Eastern region
3. Western region
4. Southern region
5. North-eastern region
6. Central region

Figure 4.1 The Kingdom of Thailand map

The area, which are an abandon field, an abandon farm, a pasture, a groove wood and a lower land, was selected based on the land use map. After done a selecting process, the map of the usable area over Thailand was shown in Fig. 4.2.

Figure 4.2 The usable area map of Thailand

4.2.1 Northern region

The northern region consists of 9 provinces which are 1. Chiangmai, 2. Chiangrai, 3. Lampang, 4. Lamphun, 5. Maehongson, 6. Nan, 7. Phayao, 8. Phrae and 9. Uttaradit, as depicted in Fig. 4.3. The total area of the Northern region is 9,409,016 ha where the largest province are Chaingmai province, Maehongson province and Lampang province, respectively.

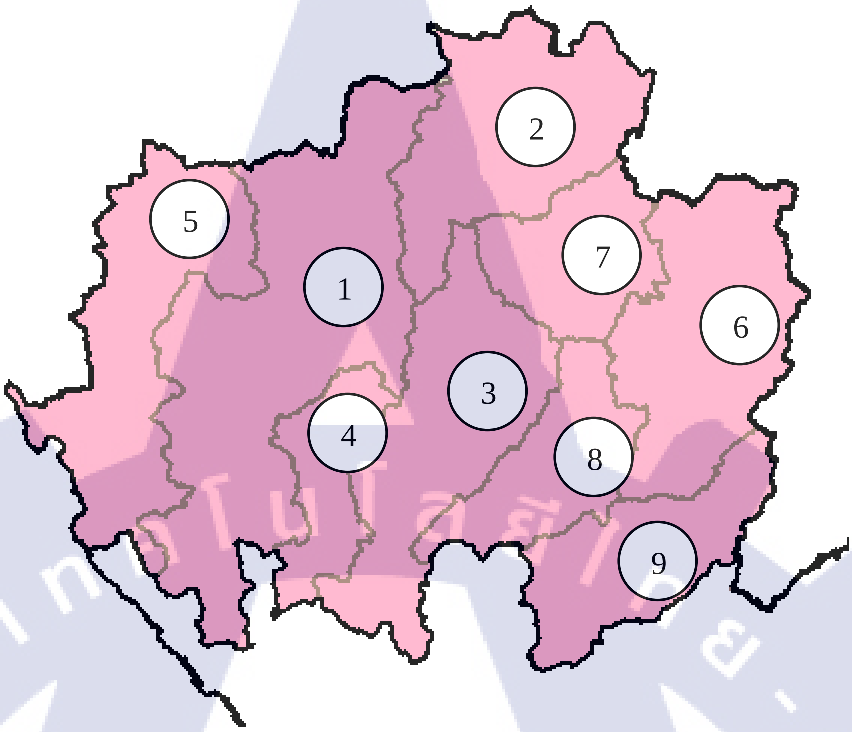


Figure 4.3 Thailand's Northern region map

After the locating process of the usable area of the Northern region for Napier grass plantation was done, all of the affected parameters were classified into a suitable classification of S1, S2, S3 and N according to the FAO framework as depicted in Fig. 4.4. Most of the suitable area of Northern region is in the rank of S1 and S2 which approximately 96% of the total usable area and the classification rank of N cannot be found in this region. The suitability classification of Phrae province, where has a maximum potential area for Napier grass plantation, was only in the rank of S1 and S2.

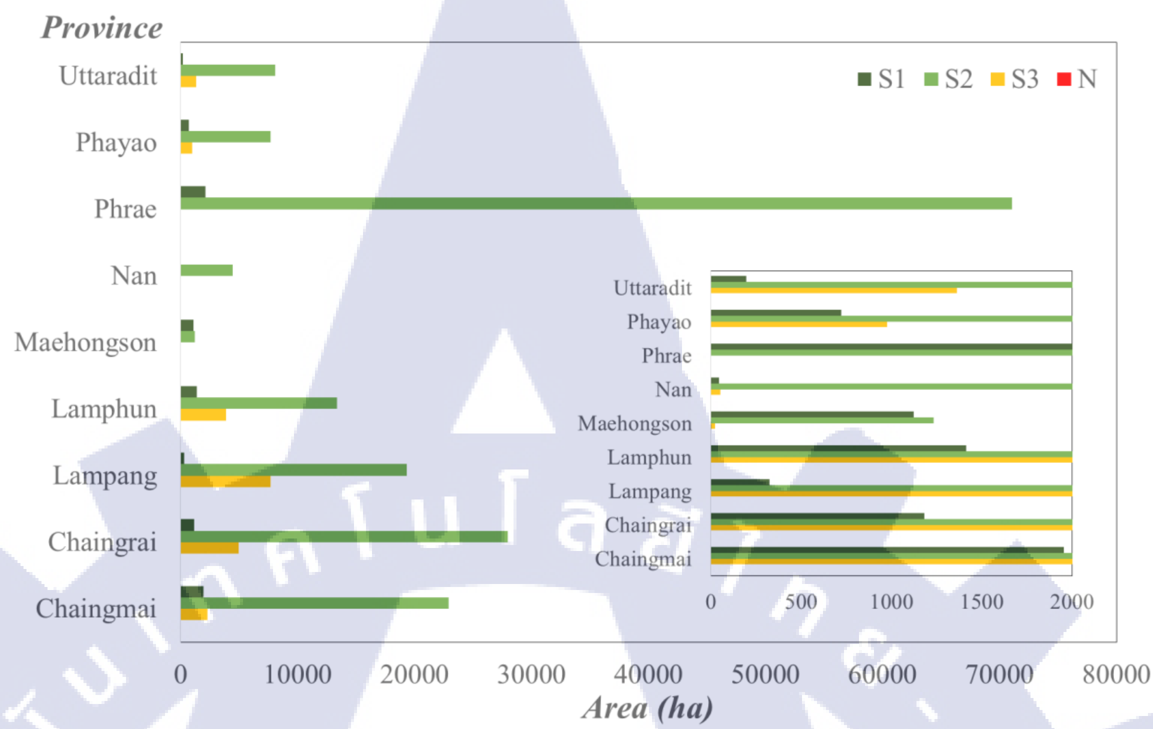


Figure 4.4 The suitability classification of the usable area in Northern region

The total usable area of each province which is obtained from the program was compared to the total geographic area to show the proportion of the area as shown in Table 4.4. The total area of the Northern region is 9,409,016 ha and the usable area is 206,416 which is approximately 2.2% of the total area. The highest usable area located in Phrae province, Chaingrai province and Lampang province which have the usable area of 73,196, 34,109 and 27,361, respectively. Although the largest province in Northern region is Chaingmai but usable area of this province was only 27,214 ha (approximately 1.4% of total geographic area) as well as Maehongson province, which is the second largest province of this region, the usable area of the province was only 2,379 ha (approximately 0.2%). From the map data, it was found that most of the area of this region was a forest area such as the forest area in Chaingmai province is approximately 1.5 million ha or 78% of total area. Since the forest area was not included in the criteria mentioned earlier, there were only a few usable area in this region.

Table 4.4 The proportion of total geographic area and usable area of each province in Northern region

No.	Province	Total geographic area (ha)	Usable area (ha)	Proportion (%)
1.	Chaingmai	2,010,706	27,214	1.4%
2.	Chaingrai	1,157,753	34,109	2.9%
3.	Lampang	1,248,823	27,361	2.2%
4.	Lamphun	447,839	18,683	4.2%
5.	Maehongson	1,278,050	2,379	0.2%
6.	Nan	1,216,301	4,390	0.4%
7.	Phayao	614,006	9,420	1.5%
8.	Phrae	648,306	73,196	11.3%
9.	Uttaradit	787,232	9,667	1.2%
Total		9,409,016	206,419	2.2%

4.2.2 Eastern region

The Eastern region, as shown in Fig. 4.5, which are 1. Chachoengsao province, 2. Chanthaburi province, 3. Chonburi province, 4. Prachinburi province, 5. Rayong province, 6. Sa Kaeo province and 7. Trat province. Total geographic area of this region is 3,448,021 ha where the largest province are Sa Keao province, Chantaburi province and Prachinburi province, respectively.

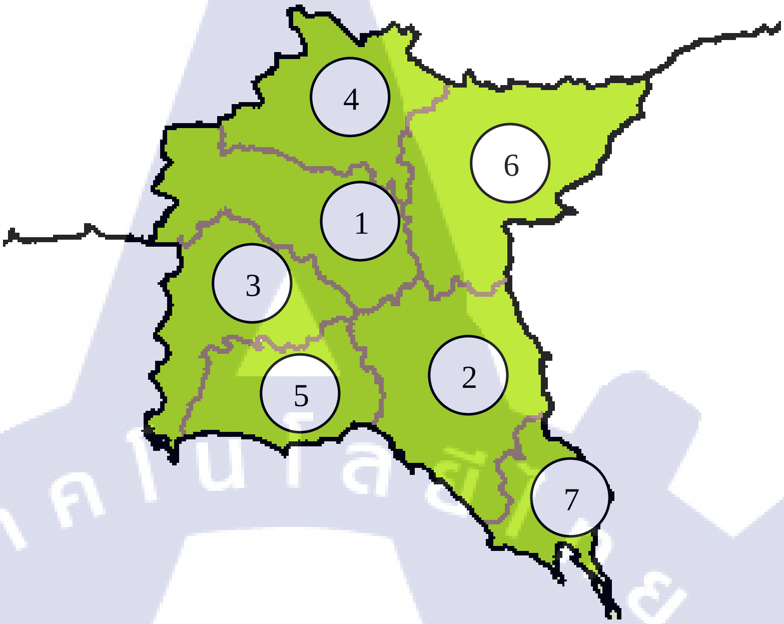


Figure 4.5 Thailand's Eastern region map

The usable area of each province in this region was located and classified into the suitable classification as depicted in Fig. 4.6. From the analyzed results, it was clearly seen that most of the suitable class in this region is in the rank of S2 and, again, the classification of N cannot be found in this region. The largest suitable area for Napier grass plantation located at Prachinburi where most of the area (approximately 89%) was in the classification of rank S1 and S2. The result from Chantaburi province shown different from other province since the usable area was in the classification of rank S3. The area which is moderately suitable for the plantation may cause by the effect of the precipitation (mostly in the range of 2000-2800 mm/year)

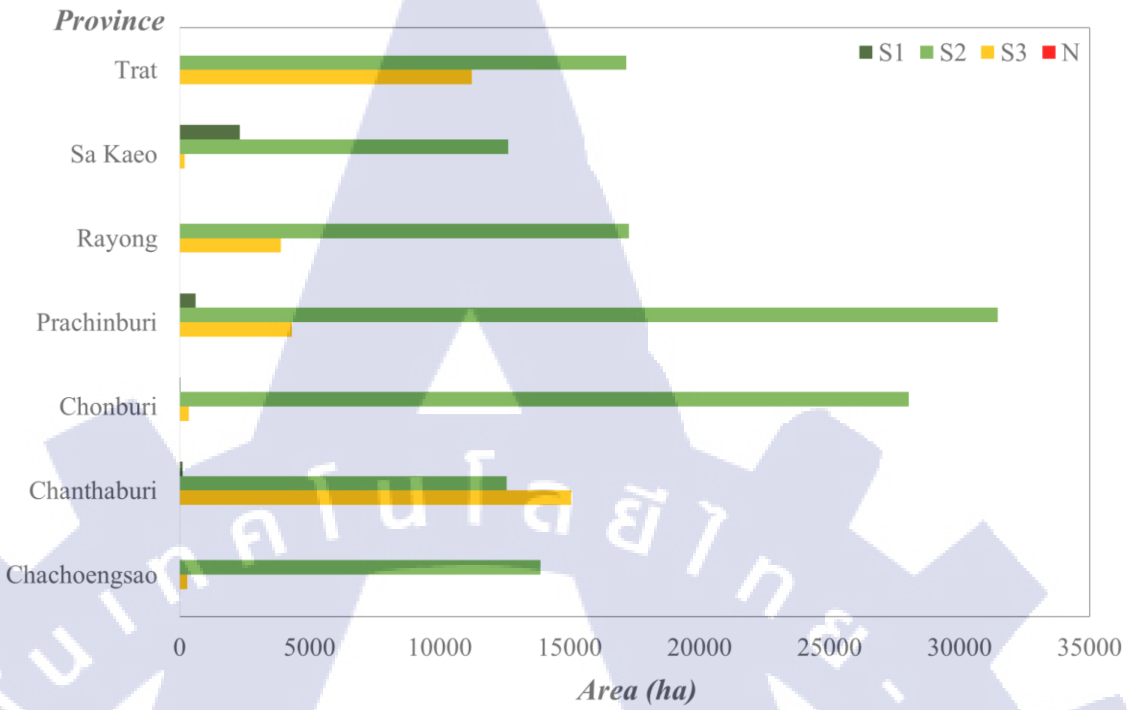


Figure 4.6 The suitability classification of the usable area in Eastern region

The proportion of the total geographic area and the usable area of each province is shown in Table 4.5. The total usable area of the Eastern region was 149,255 ha which approximately 4.3% of total area was. Although Sa Kaeo province is the largest province in this region, the usable area was only 15,159 ha (2.2% of total area) since most of the area in this province is an agriculture area and a forest area.

Table 4.5 The proportion of total geographic area and usable area of each province in Eastern region

No.	Province	Total geographic area (ha)	Usable area (ha)	Proportion (%)
1.	Chachoengsao	516,982	14,190	2.7%
2.	Chanthaburi	637,326	20,605	3.2%
3.	Chonburi	450,778	28,441	6.3%
4.	Prachinburi	503,223	36,078	7.2%
5.	Rayong	366,529	19,706	5.4%

Table 4.5 The proportion of total geographic area and usable area of each province in Eastern region (Continued)

No.	Province	Total geographic area (ha)	Usable area (ha)	Proportion (%)
6.	Sa Kaeo	686,456	15,159	2.2%
7.	Trat	286,727	15,359	5.4%
Total		3,448,021	149,548	4.3%

4.2.3 Western region

There are 5 provinces in the Western region (see Fig. 4.7) which are 1. Kanchanaburi province, 2. Phetchaburi province, 3. Prachuap Khiri Khan province, 4. Ratchaburi province and 5. Tak province. The total geographic area of this region is 5,367,901 ha. The largest province in this region are Kanchanaburi province and Tak province, respectively, where the area of these 2 provinces is approximately 66% of the total area of this region.

The usable area of each province is shown in Fig. 4.8 which classified the usable area into each suitability classification. The results of the classification was in concurrence with the Northern and Eastern region at which most of the usable area was in the classification rank of S2 and the area of classification of rank S3 cannot be found. The amount of the usable area of each province was in the range of 20,000-40,000 ha except for Ratchaburi province which is so small (around 2000 ha) as compared to other provinces.

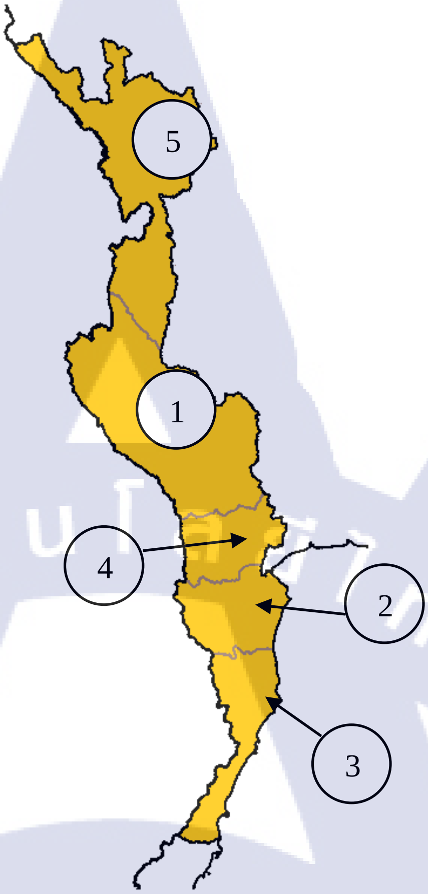


Figure 4.7 Thailand's Western region map

The total usable area of this region was shown in Table 4.6. The largest usable area was located in Phetchaburi province at which the usable area of this province was approximately 6.4% or 40,007 ha of the total geographic area.

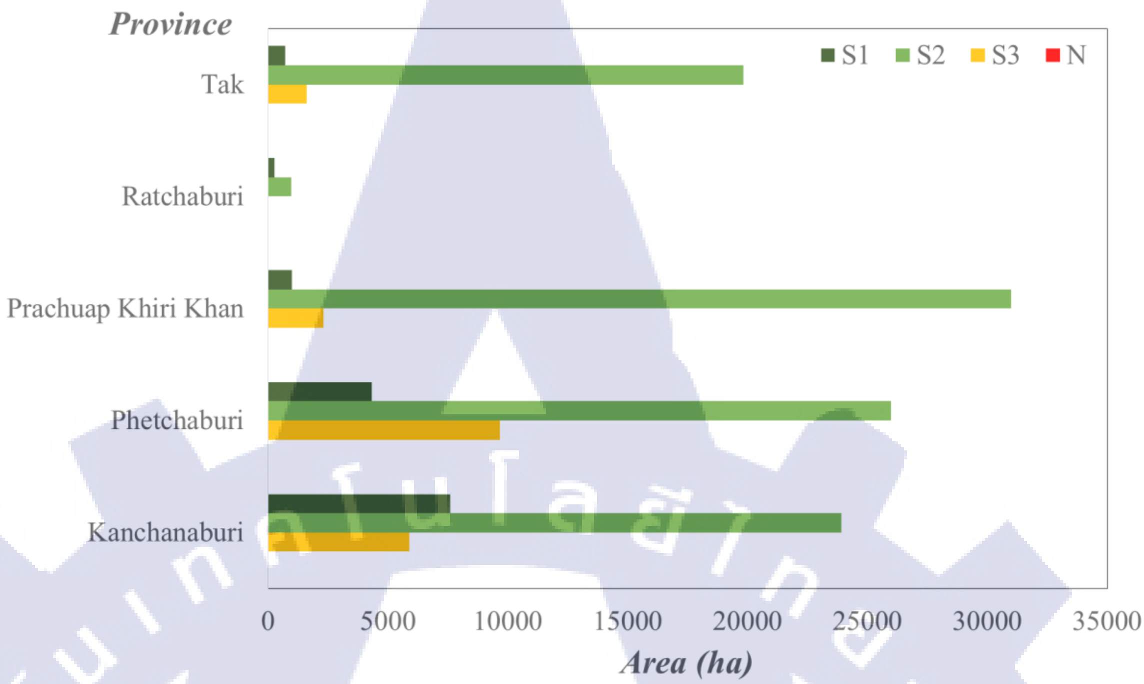


Figure 4.8 The suitability classification of the usable area in Western region

Table 4.6 The proportion of total geographic area and usable area of each province in Western region

No.	Province	Total geographic area (ha)	Usable area (ha)	Proportion (%)
1.	Kanchanaburi	1,948,314	37,456	1.9%
2.	Phetchaburi	622,514	40,007	6.4%
3.	Prachuap Khiri Khan	636,762	34,318	5.4%
4.	Ratchaburi	519,646	1,267	0.2%
5.	Tak	1,640,665	22,132	1.3%
Total		5,367,901	135,179	2.5%

4.2.4 Southern region

The Southern region consists of 14 provinces (see Fig. 4.9) of 1. Chumphon province, 2. Krabi province, 3. Nakhon Si Thammarat province, 4. Narathiwat province, 5. Pattani province, 6. Phang Nga province, 7. Phatthalung province, 8.

Phuket province, 9. Ranong province 10. Satun province, 11. Songkhla province, 12. Surat Thani, 13. Trang province and 14. Yala province. The total geographic area of this region is 7,38,251 ha where most of provinces in this region located next to ocean, except Phatthalung province.

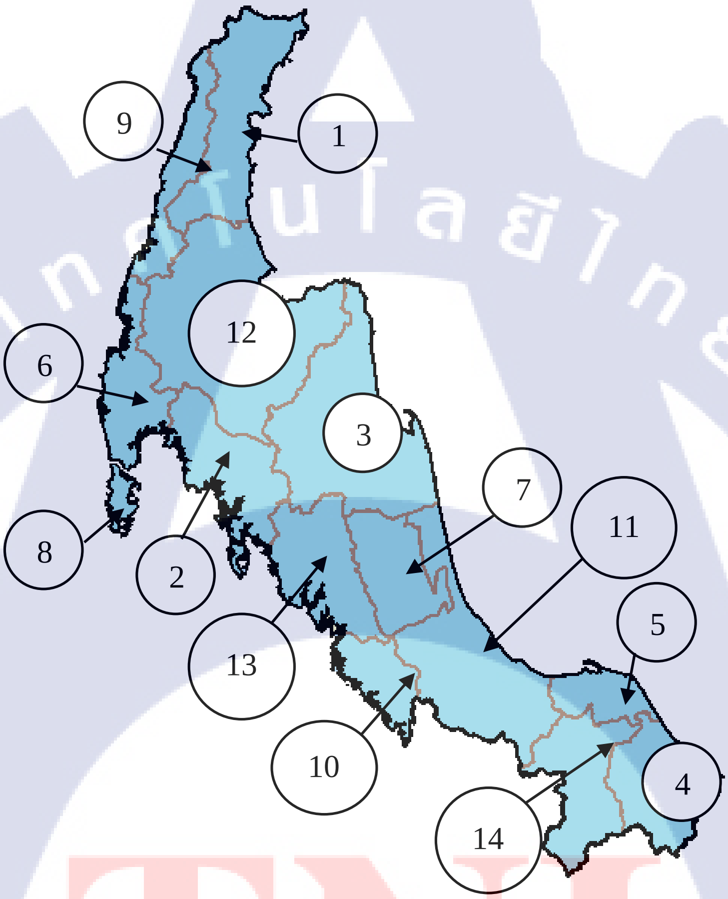


Figure 4.9 Thailand's Southern region map

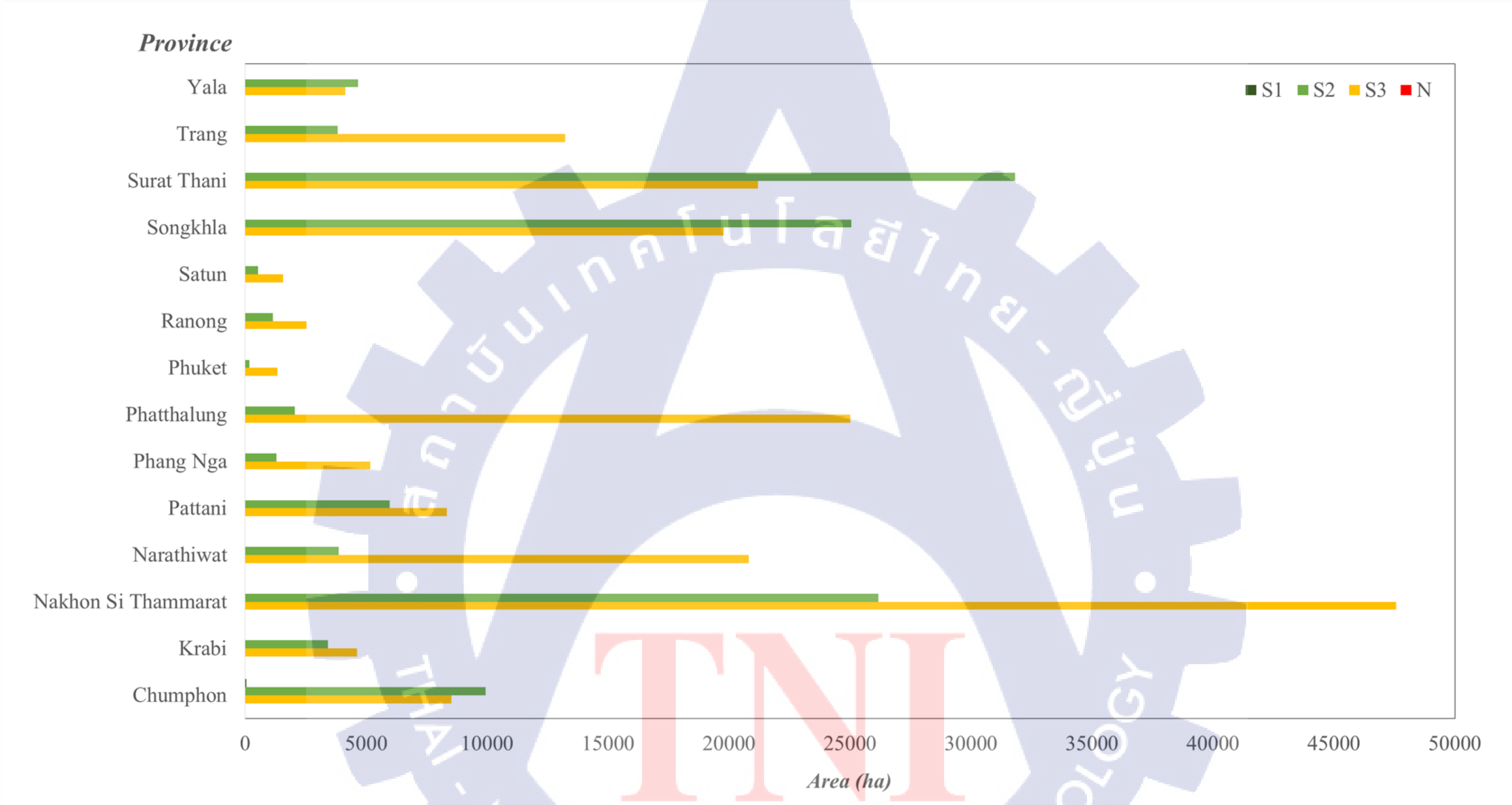


Figure 4.10 The suitability classification of the usable area in Southern region

The usable area was classified into the suitable classification which shown in Fig. 4.10. The result from the classification was found in the different way to other regions which most of the usable area were in the rank of S3. The proportion of the usable area and total geographic area is shown in Table 4.7. Although the largest usable area in this region is Nakhon Si Thammarat province (approximately 98,000 ha), more than 60% of total usable area of this province were in the suitable classification of rank S3. As mentioned earlier that most of provinces in this region are located next to the oceans, the soil pH of this region became acidity soil (pH around 5.25-6) which might be caused by seawater. The acidity soil made most of soil pH in the classification rank of S3 and N. Not only the soil pH which is mostly in not suitable classification for Napier grass plantation but also the amount of the precipitation. Most the precipitation is in the range of 1900-2200 mm/year but some provinces i.e., Rayong, Phang Nga and Phuket province reach up to 4000 mm/year which is very high as compared to other regions.

Table 4.7 The proportion of total geographic area and usable area of each province in Southern region

No.	Province	Total geographic area (ha)	Usable area (ha)	Proportion (%)
1.	Chumphon	599,621	18,527	3.1%
2.	Krabi	532,324	8,047	1.5%
3.	Nakhon Si Thammarat	988,062	73,749	7.5%
4.	Narathiwat	449,120	12,730	2.8%
5.	Pattani	197,677	10,657	5.4%
6.	Phang Nga	549,360	1,658	0.3%
7.	Phatthalung	197,677	24,836	12.6%
8.	Phuket	54,855	983	1.8%
9.	Ranong	322,502	753	0.2%
10.	Satun	302,021	2,122	0.7%

Table 4.7 The proportion of total geographic area and usable area of each province in Southern region (Continued)

No.	Province	Total geographic area (ha)	Usable area (ha)	Proportion (%)
11.	Songkhla	774,197	44,858	5.8%
12.	Surat Thani	1,307,972	53,017	4.1%
13.	Trang	473,010	17,065	3.6%
14.	Yala	447,502	8,807	2.0%
	Total	7,384,215	269,002	4.0%

4.2.5 North-Eastern region

The North-Eastern region, the largest region in Thailand, consists of 19 provinces (see Fig. 4.11) which are 1. Amnat Charoen, 2. Buriram, 3. Chaiyaphum, 4. Kalasin, 5. Khon Kaen, 6. Loei, 7. Mahasarakham, 8. Mukdahan, 9. Nakhon Phanom, 10. Nakhon Ratchasima, 11. Nong Bua Lamphu, 12. Nong Khai, 13. Roi Et, 14. Sakon Nakhon, 15. Sisaket, 16. Surin, 17. Ubon Ratchathani, 18. Udon Thani and 19. Yasothon Province. Total geographic area of this region is 16,700,839 ha and the largest province in this region and also in Thailand is Nakhon Ratchasima province which area of this province is 2,072,722 or approximately 12% of total geographic area of this region.

The selected area was classified in the suitability classification which shown in the classification of rank S1, S2, S3 and N (Fig. 4.12). From the analysis, it was clearly seen that most of the usable area was in the classification of rank S2 which the result was in concurrent to another region. The suitability class of S1 and N was also found, but only a few as compared to rank S2.

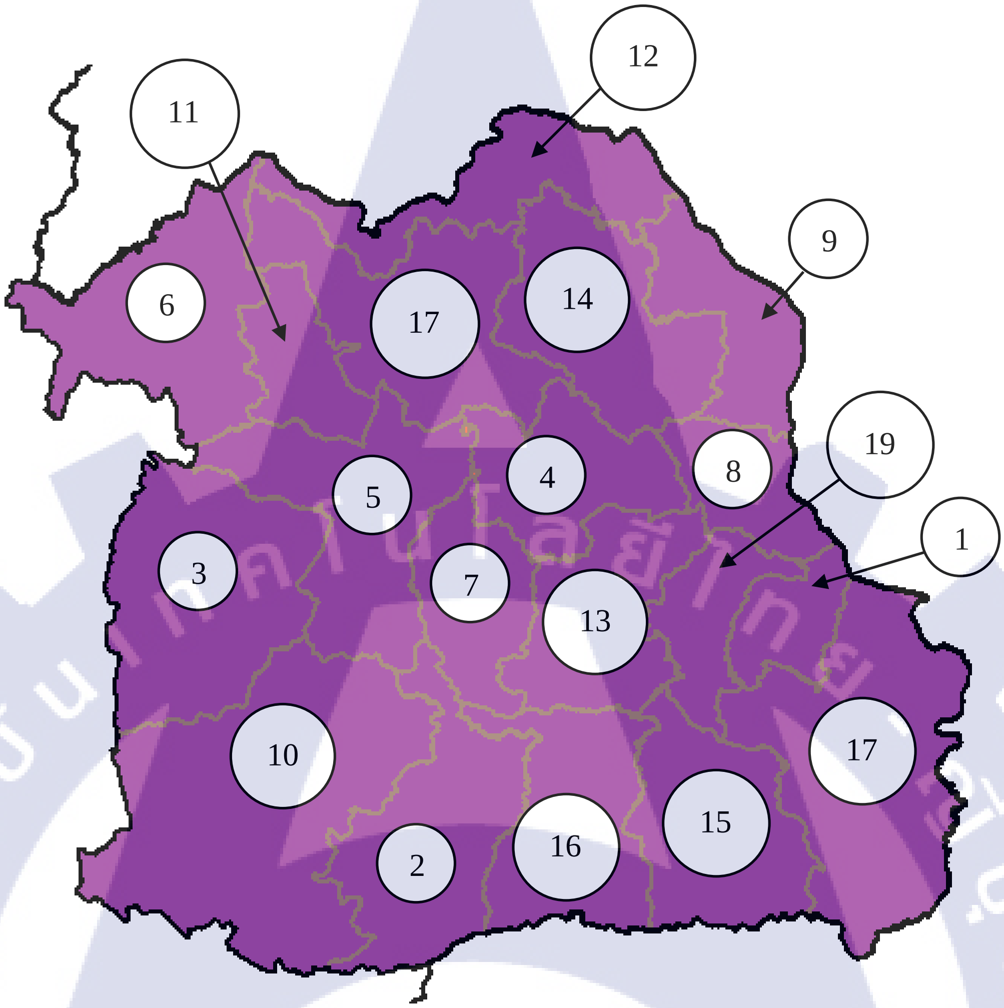


Figure 4.11 Thailand's North-Eastern region map

However, the suitability class of N cannot be found in this region. The proportion of total geographic area and usable area of each province in North-Eastern region was shown in Table 4.8. Although the largest province in this region is Nakhon Ratchasima province, the largest usable area located in Ubon Ratchathani province. Since more than 50% of total area in Nakhon Ratchasima province is an agricultural area and there is only 0.4% from the agricultural area was an abandon field and farm. The smallest usable area in this province is Loei province which the usable area was only 1% of total area since more than 90% of total area of this province is an agricultural and forest area.

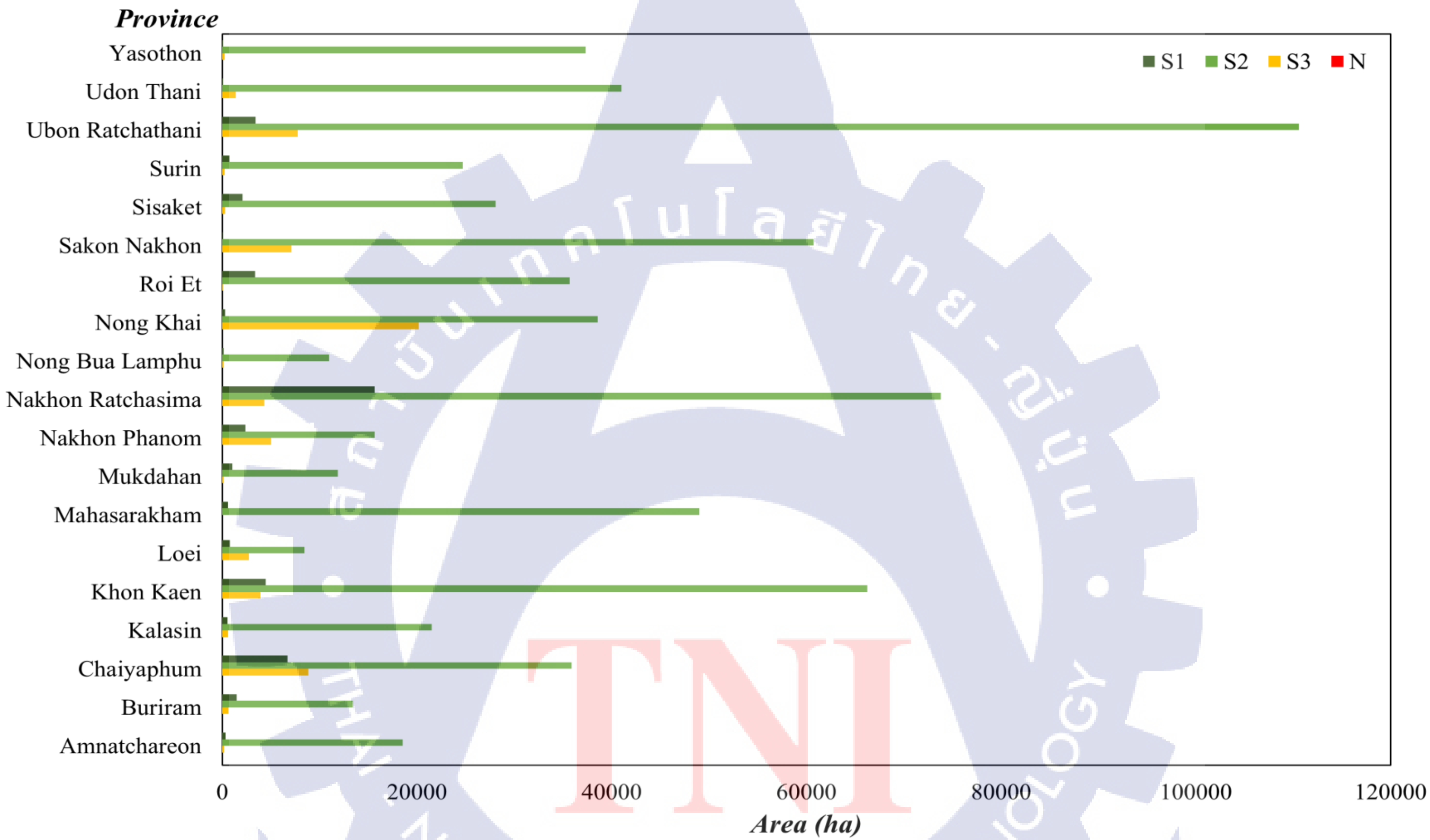


Figure 4.12 The suitability classification of the usable area in North-Eastern region

Table 4.8 The proportion of total geographic area and usable area of each province in North-Eastern region

No.	Province	Total geographic area (ha)	Usable area (ha)	Proportion (%)
1.	Amnat Charoen	409,517	19,110	4.7%
2.	Buriram	1,004,619	15,529	1.5%
3.	Chaiyaphum	1,270,720	51,427	4.0%
4.	Kalasin	689,838	22,636	3.3%
5.	Khon Kaen	1,063,860	74,644	7.0%
6.	Loei	1,051,296	11,959	1.1%
7.	Mahasarakham	558,604	49,620	8.9%
8.	Mukdahan	409,113	13,049	3.2%
9.	Nakhon Phanom	558,909	22,768	4.1%
10.	Nakhon Ratchasima	2,072,722	93,763	4.5%
11.	Nong Bua Lamphu	326,140	11,246	3.4%
12.	Nong Khai	724,586	59,095	8.2%
13.	Roi Et	782,355	39,157	5.0%
14.	Sakon Nakhon	952,134	67,876	7.1%
15.	Sisaket	886,255	30,473	3.4%
16.	Surin	880,402	25,684	2.9%
17.	Ubon Ratchathani	1,546,126	121,737	7.9%
18.	Udon Thani	1,103,982	42,527	3.9%
19.	Yasothon	409,661	37,663	9.2%
Total		16,700,839	809,965	4.8%

4.2.6 Central region

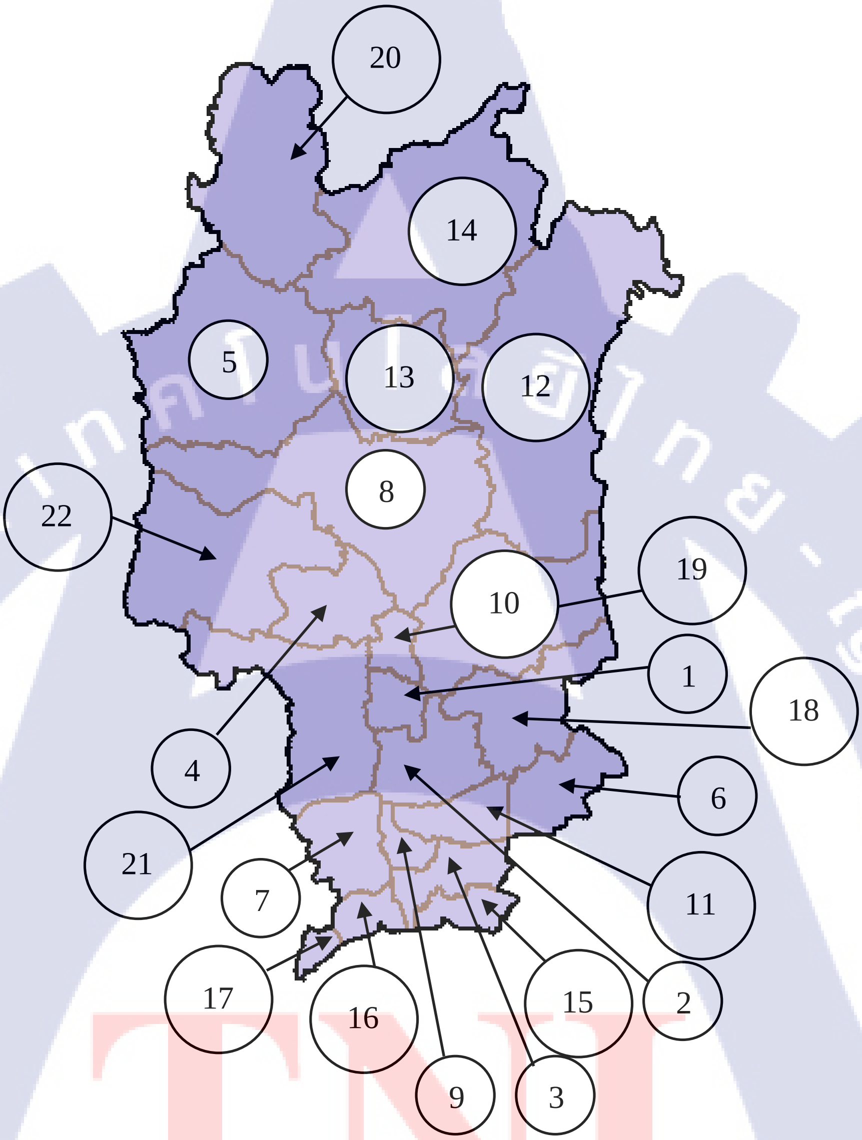


Figure 4.13 Thailand's Central region map

The Central region of Thailand consists of 22 provinces (see Fig. 4.13) which are 1. Ang Thong, 2. Ayutthaya, 3. Bangkok, 4. Chainat, 5. Kamphaeng Phet, 6. Nakhon Nayok, 7. Nakhon Pathom, 8. Nakhon Sawan, 9. Nonthaburi, 10. Lopburi, 11. Phathum Thani, 12. Phetchabun, 13. Phichit, 14. Phitsanulok, 15. Samut Prakan, 16. Samut Sakhon, 17. Samut Songkhram, 18. Saraburi, 19. Singburi, 20. Sukhothai, 21.

Suphanburi and 22. Uthai Thani province. The total geographic area of this region is 9,100,523 ha. The largest province is Phetchabun province (approximately 13% of total area of this region) where is one of the pilot plant for Napier grass plantation. The smallest province is Samut Songkhram province which the area is only 40,905 ha.

The usable area of this region which classified into each classification and the proportion of usable area and total geographic area was shown in Fig. 4.14 and Table 4.9, respectively. However, in the classification method, the usable area from Samut Sakhon province was not included in this model since the soil data from soil map of this province is not available. Therefore, the geographic area of this region was decrease to 9,014,109 ha. Most area in this region is almost the same as other regions which are used for an agricultural propose. The result from the classification was obviously seen that the result was mostly in the classification of rank S2 and the classification of rank N cannot be found in this region. The largest usable area located in Phitsanulok province which more than 80% of the area are in the rank of S1 and S2. The classification of rank N in this province might occur by the poor quality of soil pH since more than 95% was ranked in the suitability classification of rank S3 and N. The smallest located in Samut Prakan province which area was only 288 ha.

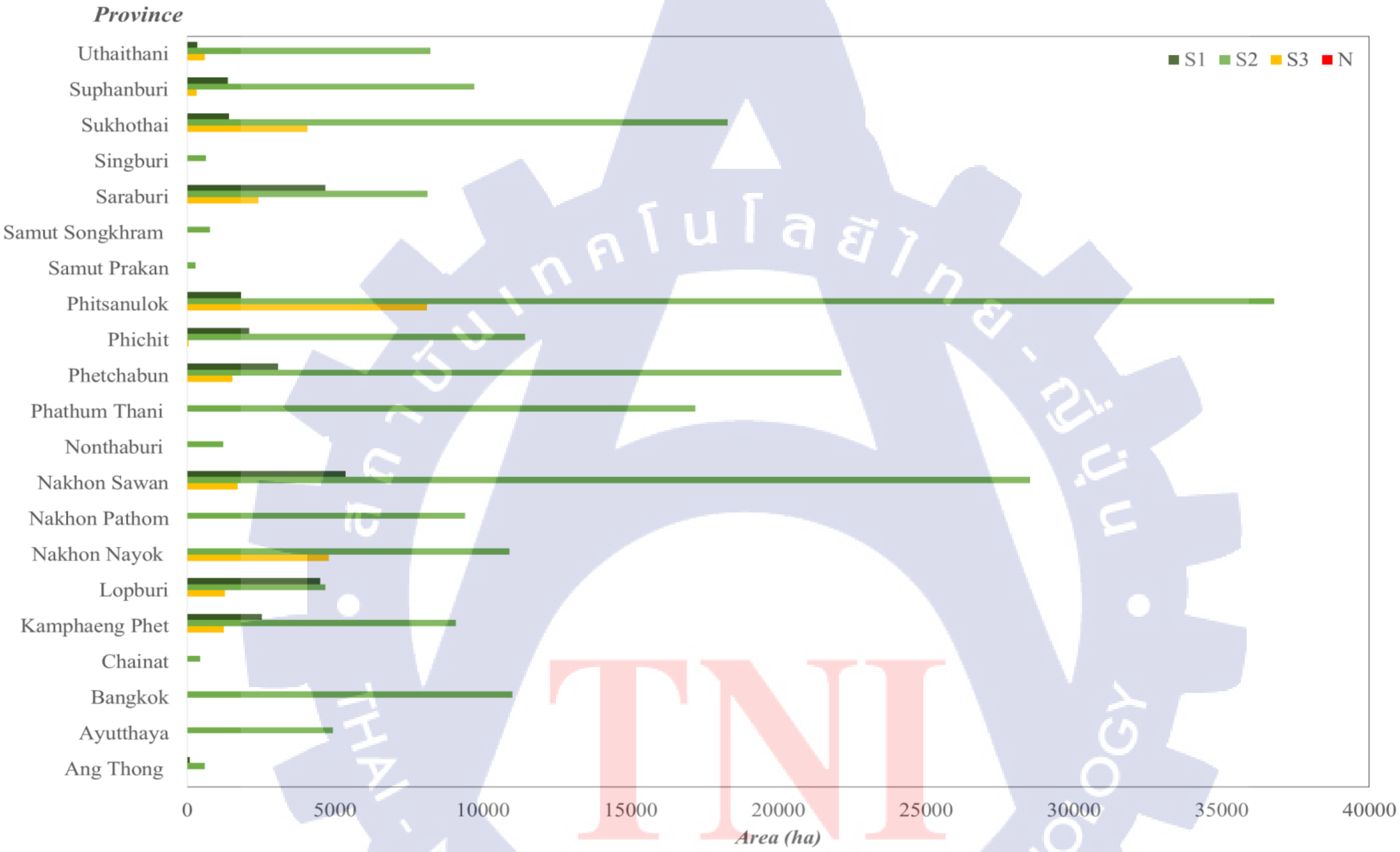


Figure 4.14 The suitability classification of the usable area in Central region

Table 4.9 The proportion of total geographic area and usable area of each province in Central region

No.	**Province**	**Total geographic area (ha)**	**Usable area (ha)**	**Proportion (%)**
1.	Ang Thong	94,868	674	0.7%
2.	Ayutthaya	253,407	4,947	2.0%
3.	Bangkok	155,866	11,004	7.1%
4.	Chainat	246,343	452	0.2%
5.	Lopburi	861,916	12,875	1.5%
6.	Kamphaeng Phet	629,079	10,477	1.7%
7.	Nakhon Nayok	214,617	15,307	7.1%
8.	Nakhon Pathom	214,344	9400	4.4%
9.	Nakhon Sawan	950,174	35,574	3.7%
10.	Nonthaburi	63,533	1,222	1.9%
11.	Phathum Thani	151,783	17,200	11.3%
12.	Phetchabun	1,242,250	26,746	2.2%
13.	Phichit	432,078	13,575	3.1%
14.	Phitsanulok	1,061,284	46,733	4.4%
15.	Samut Prakan	94,909	288	0.3%
16.	Samut Sakhon	(86,414)	-	-
17.	Samut Songkhram	40,905	780	1.9%
18.	Saraburi	348,819	15,230	4.4%
19.	Singburi	83,163	647	0.8%
20.	Sukhothai	668,936	23,771	3.6%
21.	Suphanburi	540,644	11,416	2.1%
22.	Uthaithani	665,191	9,170	1.4%
Total		9,014,109	267,487	3.0%

To give a better understanding in land suitability evaluation, the suitable areas at different classifications of suitability based on soil fertility, soil drainage, pH, precipitation and overall. The selected area was from Phrae province from Northern region and Nakhon Si Thammarat province from Southern region since the result from these province give a different in a contour level.

The suitability map of Phrae province was shown in Fig. 4.15 (a)-(e) which shown in suitability class of each effected factors. The factor of soil drainage and soil fertility (Fig. 4.15 (a)-(b) was shown in the same direction since most of them was in the classification of rank S2 and area with the classification of rank S1 and S3 dispersed in the middle area of Phrae province. The suitable class of N was found only in a small area of soil fertility suitability map but cannot be found in soil drainage map. The different result was found in soil pH map (Fig 4.15 c) since most of them was in the classification of rank S3 and the other rank was found dispersing all over Phrae province which the pH of this province was around 6-7. The map of precipitation was shown in Fig. 4.15 d where most of them was in the classification of rank S1 and S2. The precipitation of this province was around 1,000-1,450 mm/year and some of the area in the southern area was around 1,500 mm/year which was rank into the classification of rank S2. However, the result from overall suitability map was found only in the rank of S1 and S2.

The result of Nakhon Si Thammarat province was shown in Fig. 4.16 (a)-(e). Soil drainage map (Fig. 4.16 a) where most of them was in the classification of rank S1 and S2 and only a small area was found in the upper area of this province. Most of the area soil fertility classification was in the rank of S3 and S2. The poor soil pH was found all over this province where most of them was in the rank of S3 since it may caused by the effect of seawater. The result form the classification of precipitation map was found that the area which is located next to the ocean has the high amount of precipitation. The overall suitability map was shown in Fig. 4.16 e which is classified only in the rank of S2 and S3.

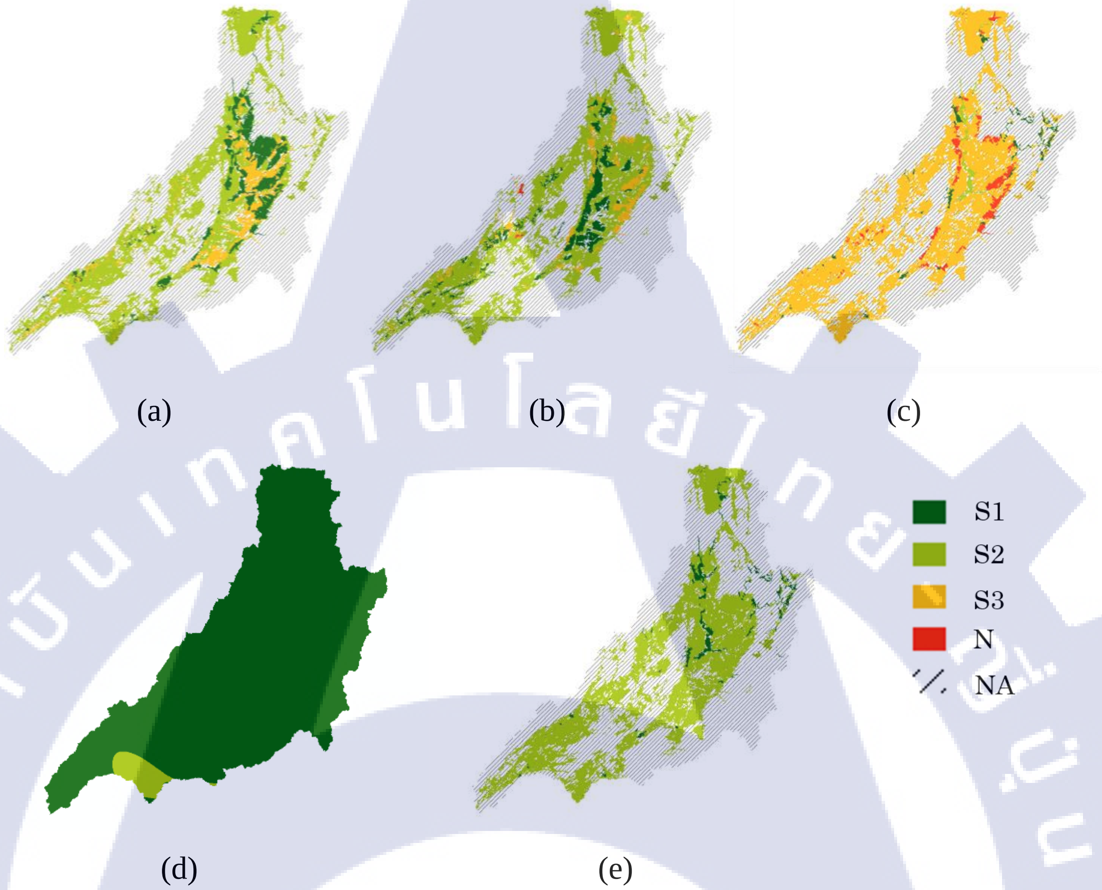


Figure 4.15 The land suitability map of Phrae province a) soil drainage, b) soil fertility, c) soil pH, d) precipitation and e) overall suitability

Since the result from land evaluation analysis can only show the qualitative result but the production yield cannot be known. Therefore, the dry matter yield was predicted by using the affected parameters which is obtained from usable area which will be discussed in next section.

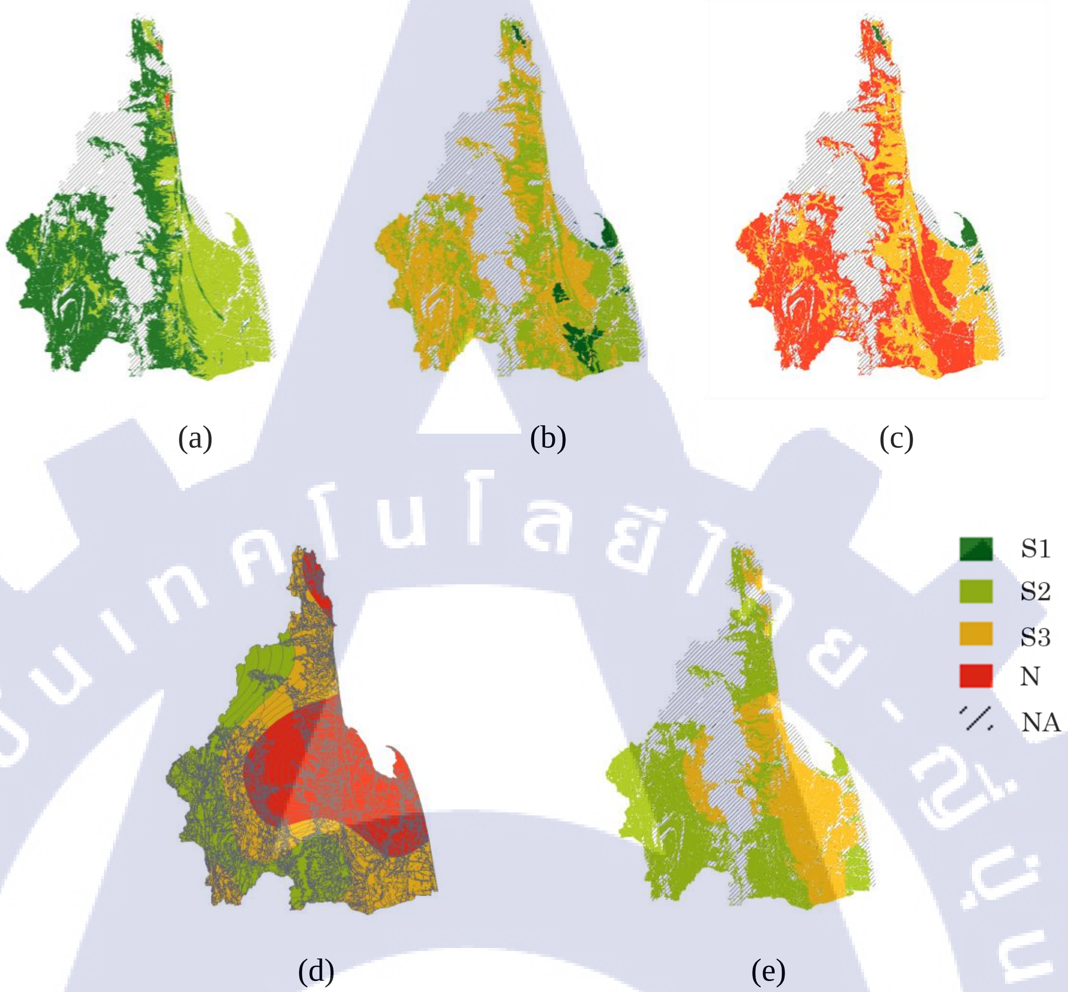


Figure 4.16 The land suitability map of Nakhon Si Thammarat province (a) soil drainage, (b) soil fertility, (c) soil pH, (d) precipitation and (e) overall suitability

4.3 Evaluating the potential of Napier grass yield

The potential of Napier grass yield was evaluated by using multiple regression model (eq. 2.2). The dry matter yield from usable area was obtained and compared the result of the usable area and their yield (see Fig. 4.17). It was clearly seen that the largest amount of usable area located in North-Eastern region and also give a largest amount of production yield. The second largest usable area was at Southern and Central region. Since the amount of usable area in both region were nearly the same but the S3 area in Southern region was very high as compare to the other regions. The amount of the usable area from Northern, Eastern and Western region were almost the same If the S3 area is neglected, the result from Southern region was almost the same as those 3 regions (Northern, Eastern and Western region). Surprisingly, the predicted production yield of Northern region was high as compared to its usable area.

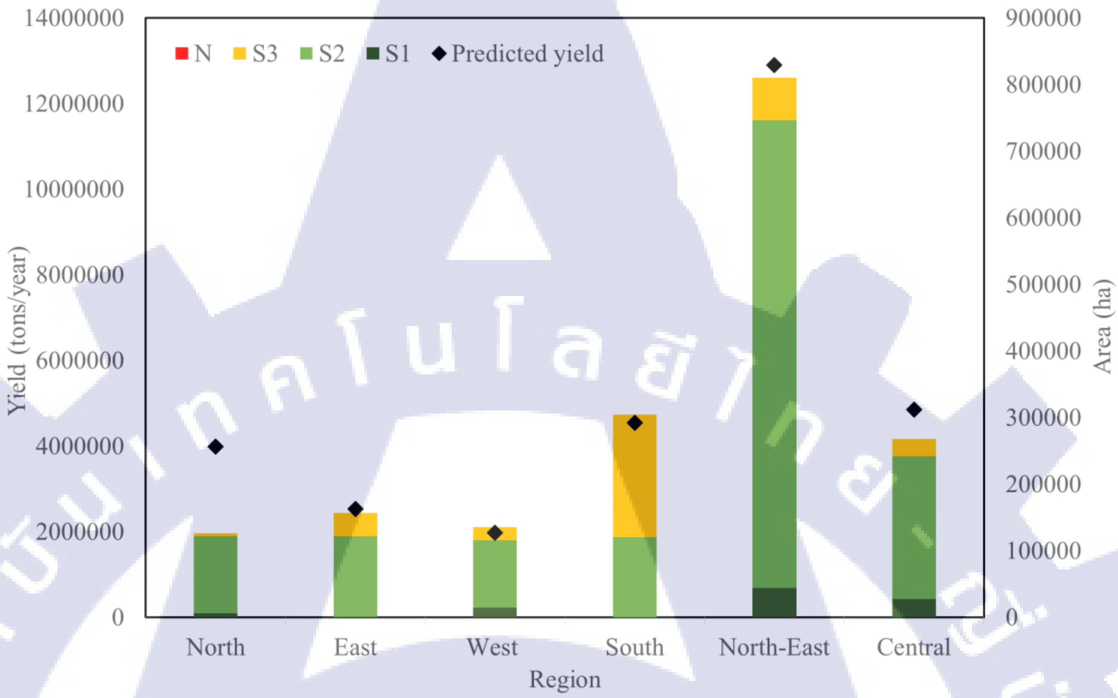


Figure 4.17 The comparison of the usable area of each region which classified in suitability rank and dry matter yield shown by region

Table 4.10 The average yield of each classification

Region	**Average yield (tons/ha)**		
	S1	**S2**	**S3**
1. North	23.5	17.5	9.5
2. East	24.1	15.8	13.7
3. West	24.0	14.7	8.3
4. South	28.2	13.5	9.2
5. North-East	21.74	17.1	10.3
6. Central	23.0	21.0	11

To see the trend of the predicted yield which can be obtained from each suitability classification, the average yield was shown in Table 4.10. Since the classification showed only in the suitability rank of S1, S2 and S3, therefore, the rank of not suitability was not included in this table. The average yield of rank S1, S2 and S3 were in the range of 21-28, 13-21 and 8-13 tons/ha, respectively.

The dry matter yield of each region was shown in Fig. 4.18 (a)-(b) and Fig. 4.19 (a)-(d) which shown the result in the proportion of each province. The Napier grass yield of Northern region was shown in Fig. 4.18 (a). The result was in concurrence with the number of the amount of usable area since Phrae province gave a largest usable area and also give a high amount of yield. More than 44% of the total yield were from Phrae province and the second largest amount of the yield was from Chaingrai province.

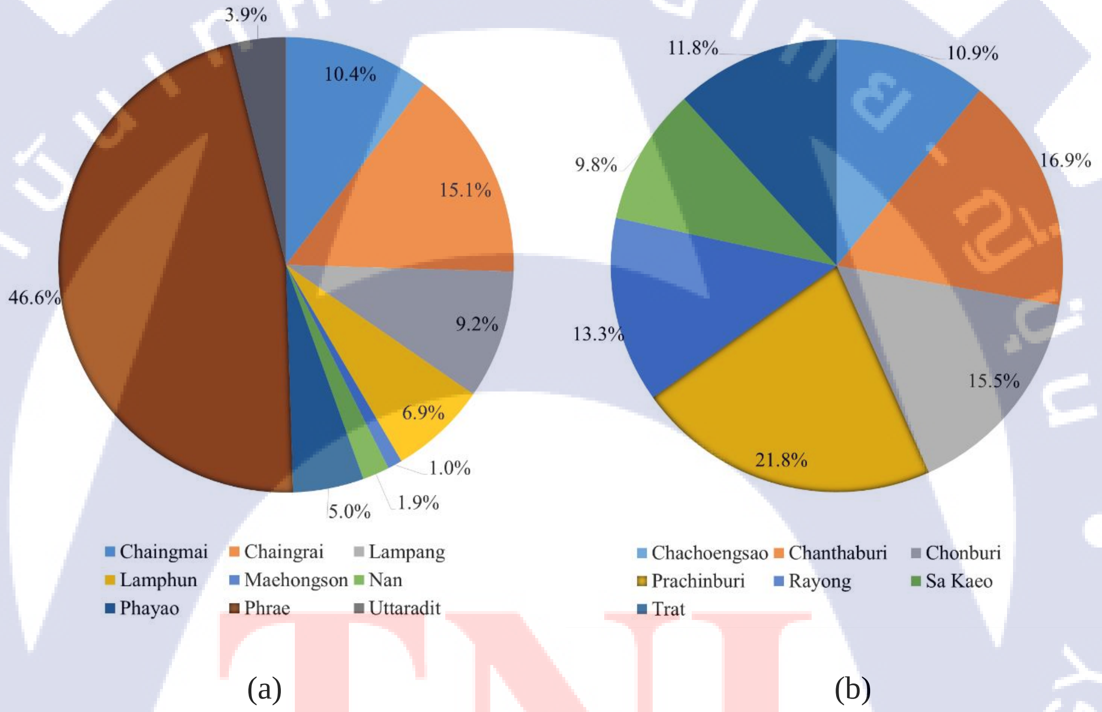


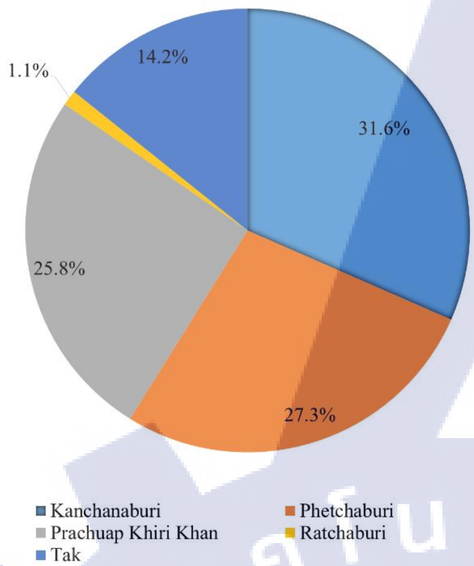
Figure 4.18 The dry matter yield of (a) Northern and (b) Eastern

The yield proportion of Eastern region was shown in Fig. 4.18 (b). The highest amount of Napier grass yield was obtained from Prachinburi province and the second high of potential yield located at Chantaburi province. The result of the rest province was nearly the same since proportion was in the range of 10-15%. However, as compared to the total usable area, Sa Kaeo province provide a very small production yield. The Napier grass yield of Western region was shown in Fig. 4.19 (a), the most of the proportion Napier grass yield of this region located at Tak, Prachuab Khiri Khan and Phetchaburi province which aprroximately 85% of total production yield from this region. The smallest yield came from Ratchaburi province which was in concurrent to the result from locating the suitable area where the area of this province was only 1266 ha. The production yield of Southern region was shown in Fig 4.19 (d), it was clearly seen that the highest yield was obtained from Nakhon Si Thammarat where also the largest usable area located.

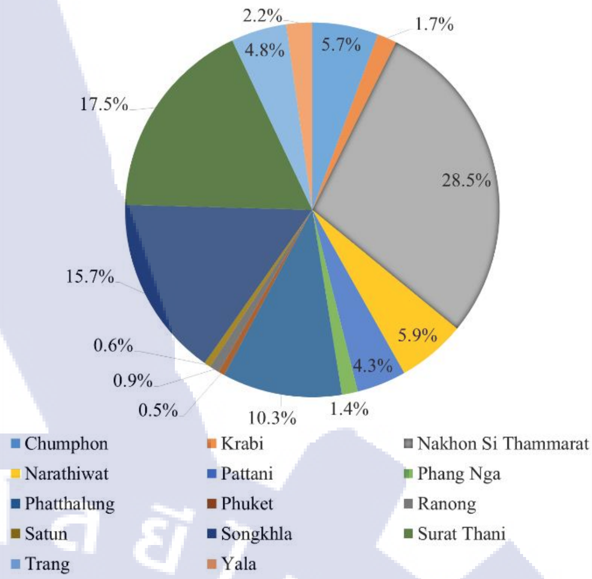
The lowest amount of Napier grass yield was found at Phuket, Ranong and Satun province which the yield proportion of these provinces were only 0.5, 0.9 and 0.6%, respectively. The proportion of Napier grass yield of North-Eastern region was shown in Fig. 4.19 (a). The highest yield was found at Ubon Ratchathani province which approximately 14.1% of total yield production. The lowest yield was obtained from Loei and Mukdahan province. The last region of Central region was depicted in Fig. 4.19 (b), the highest yield was found at Phitsanulok province and the second highest yield was obtained from Nakhon Sawan province. The lowest yield with a result of not exceed 1% of total yield was obtained from Ang Thong, Chainat, Nonthaburi, Samut Prakan, Samut Songkhram and Singburi province.

After the analysis was done, the area, which is most suitable to be first started plant for Napier grass plantation, was the North region. Although it cannot give a largest usable area, it can give a high amount of Napier grass yield as compared to its usable area.

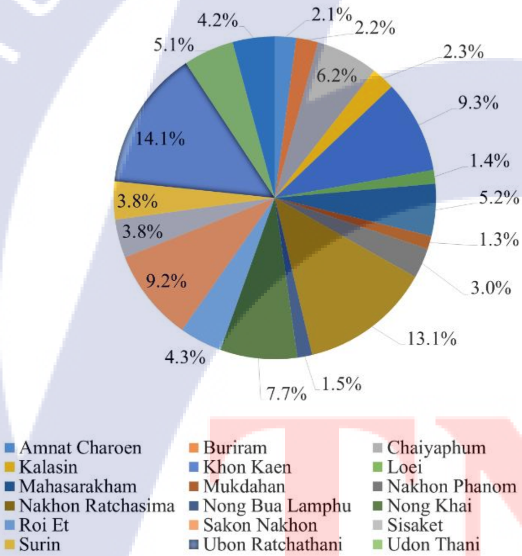
The result from locating the suitable area was found that Thailand has a usable area of 1.8 million ha with a maximum potential of 30 million tons. The usable area is high as compared to target plan since it needs only 480,000 ha. However, the obtained available area is higher than estimated target but the predicted yield which obtained from the model was only 30 million tons which equal to the estimated target.



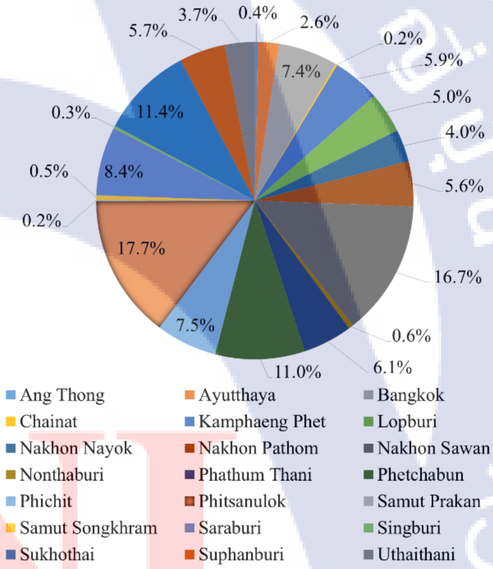
(c)



(d)



(a)



(b)

Figure 4.19 The dry matter yield of (a) Western, (b) Southern region (c) North-Eastern and (d) Central region

Although the result from the analysis was found that there were a large gap between the target plan and estimated target but the result can be suggested the first-started pilot plantation which should be the area with suitable of classification of S1 and S2 since they has a potential for an improvement.

Chapter 5
Conclusions and Recommendations

5.1. Conclusions

The conclusions on the locating the suitable area and evaluating the potential of Napier grass yields in Thailand using ArcMap 10.0 are summarized here as follows.

The model of locating the usable area over Thailand area successfully developed. The obtained data from map and predicted yield from the model are validated with the data from reports. The result was in concurrent with the validated data. However, some of the different data may cause by the error from map data.

After locating the suitable area method in Thailand, the usable area was 1.8 million ha or approximately 3.5% of total geographical area of Thailand. It was found that most of the area in Thailand was in the classification of rank S2 and the classification of rank N cannot be found. The largest usable area located in North-Eastern region which approximately 45% of total usable area.

The maximum potential of Napier grass plantation, which obtained from soil properties from map data, was approximately 30 million tons. The area where give highest yield was also found at North-Eastern region.

The usable area is high as compared to target plan since it needs only 480,000 ha but the predicted yield was only 30 million tons which equal to the estimated target which mean the predicted yield was less than the evaluated yield for more than 300%.

5.2. Recommendations

The recommendations that could be implemented for further research to receive better results are described as follows.

- The error of the predicted yield might cause by the model since it was a simple linear equation. Some of the factor and dry matter yield might not be able to describe by linear model. Therefore, to improve the accuracy of the model, a non-linear model is required to solve this problem.

- The geographic factors alone might not enough for the dry matter yield prediction. The model which include the effect of man-made factors is required.
- Since usable area was obtained but some of them were very small (less than 0.5 ha) which might not worth to plant the Napier grass. However, the plan for the use of land in such case of the distance between areas and gas pipe.

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