AN APPLICATION OF GEO-INFORMATICS TO IDENTIFY THE VULNERABLE AREAS OF PEATLAND IN THELE-NOI WETLAND, SOUTHERN THAILAND

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ABSTRACT: Wetlands in the Thale Noi non-hunting area are the important sources of water, food and households industry of the communities around the area. An increasing demand of agricultural land leads to the inappropriate utilization of peatland that, in turn, continuously affects the ecology of the wetland. The objective of this research is to apply satellite data to track the peatland changes in the Thale Noi non-hunting area and evaluate the risk of the changes, using analytical hierarchical process (AHP) with data analysis in a GIS. The findings of this study will be used to produce land use zoning guidelines in the area. The result of the study from 2002 to 2009 shows that the peatlands of 7,091.08 rais became a conglomeration of abandoned lands, marshland, oil palm plantation, shrimp ponds, fish ponds, and paddy fields. The analysis of the vulnerability of the changes in the lands shows that most of the risk areas are at the boundaries of the agricultural areas, peatlands, abandoned peatlands, and marshland. The vulnerable areas account for about 54,911.02 rais or 87.85 square kilometers or the equivalent of 27.72 percent of the peatlands in the Thale Noi non-hunting area.

INTRODUCTION

Thale Noi wetland or Thale Noi non-hunting wetland was declared to be non-hunting on 18 February 1975 and was considered the first non-hunting area of Thailand under the Department of the National Park, Wild Animals, and Flora, the Ministry of Natural Resources and Environment. The area of the wetland consists of 2 parts (1) a land part which has the feature of a field of tidal flat, a large peat swamp forest, and a plain (2) a water part which has a feature of a round water area being an important water source for the surrounding communities (DNP, 2006). Furthermore, there is another Khuan Kreng swamp surrounding Thale Noi wetland like a ring. The wetland of Thale Noi is considered to be the perfect area for the national swamp as it contains an important biological variety of the country specifically the area of the inner swamp called Kuan Ki Sian which has been Thailand Kuan Ki Sian of Thale Noi Non-Hunting Area wetlands or the first Ramsar Site of the country or the 948th of the world list since 13-May-98 (The Ramsar Convention on Wetlands, 2011). The Thale Noi wetland is a source of water together with waste water before it flows to Thale Noi and Songkhla Lake. The wetland helps balance nature while maintaining the biological varieties and a source of different plant and animal cultivations. Moreover, it is a source of food and sedge which is an important raw material for the household industry of the surrounding communities. Today, there are a great deal of changes around the area of the Thale Noi wetland and Khuan Kreng especially the land invasion for the ongoing expansions of the oil palm plantations as well as the increasing needs of water for agricultural purposes. What follows is that the level of water flowing into the forest reduces dramatically that causes the forest fire during the dry season of every year. This has severely impacted the eco-system of the natural swamp (MACORIN, 2009). It also speeds the release of Greenhouse Gas: GHG especially more carbon dioxide (CO_2) from the swamp area (UNFCCC, 2005). However, in some year, during the rainy season when there was high quantity of the rainfall, the area was flooded and the aforementioned agricultural area was damaged (ONEP, 2000).
Geo- informatics technology, especially the satellite image information, the aerial photograph of different timings, and the information from the Geographic information System (GIS), can be effectively used in the following up, examining, and analyzing of the area (Mui-How Phua *et al*., 2005; L.-M. Rebelo *et al*., 2009). This present study aims to use the information of the satellite image, THEOS and SPOT together with the aerial images of different timings to study the changes in the Thale Noi non-hunting area and to analyze it with the database of the relevant GIS. The Analytic Hierarchy Process: AHP is used with the GIS as a tool for the Multi-Criteria Analysis: MCA which can properly evaluate the suitable capability of the determined area (Marianna Garf *et al*., 2011; WEI Lai *et al*., 2011). The study of the risk or the vulnerability for change of the swamp in Thale Noi non-hunting area can lead to a guideline in determining the applicable area within this non-hunting site.

STUDY AREA

The wetland in Thale Noi Non-Hunting Area is located to the north of Songkhla Lake covering the land of 3 provinces i.e. Phatthalung, Songkhla, and Nakhon Si Thammarat with the total area of approximately 460.64 square kilometer or 287,898 rai (ONEP, 2011). Its topography feature is plain, swamp forest, wet and contains water almost all year round. The annual rainfall quantity is about 1,900-2,000 millimeter per year. The heavy rain is between October and December while the average temperature is about 27-28 degree Celsius (Thai Meteorological Department, 2010). The water source of this non-hunting area consists of a large water swamp or Thale Noi covering an area of approximately 26.64 square kilometer or 16,250 rai with many short distant canals flowing into Songkhla Lake. Most of the land use condition is around the area of plain and peatland forest, cajuput tree, sedge, and grassland. The area around the boundary of the peatland is also used as animal fields, places for the collection of wild items, oil palm plantations and paddy fields, as illustrated in figure 1.

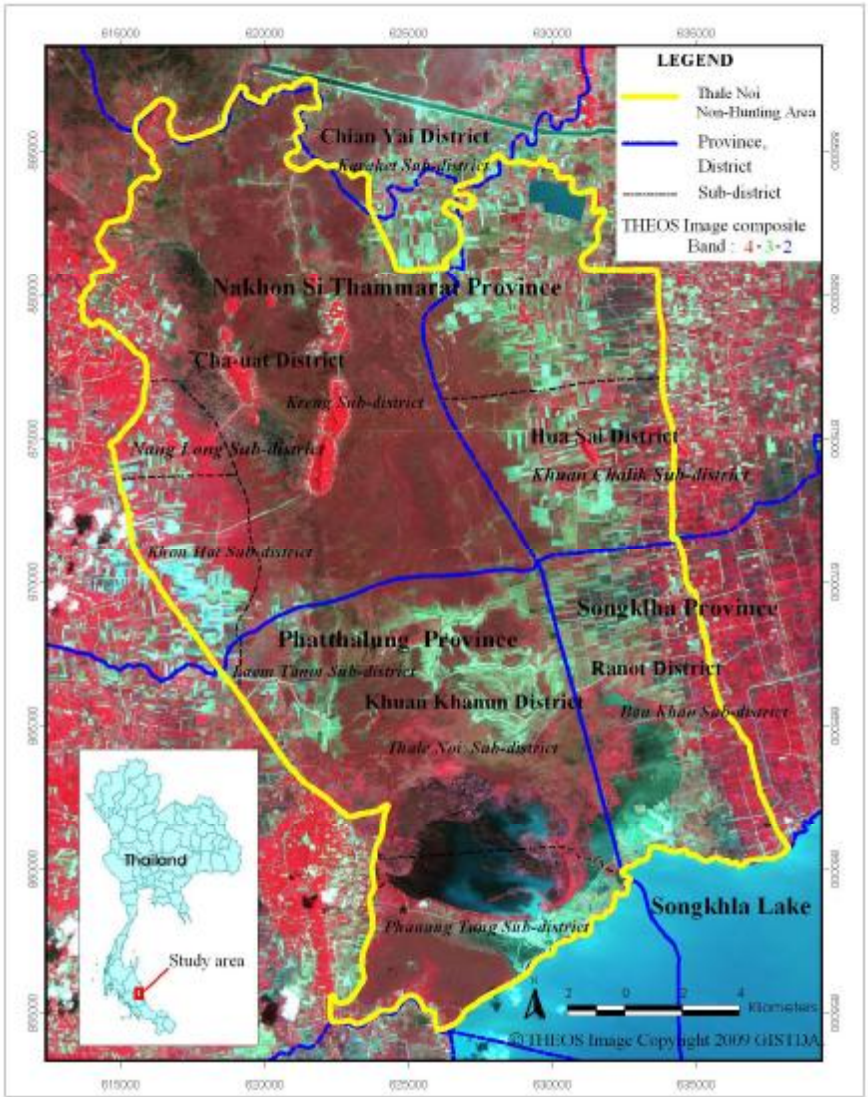

Figure 1: The study area of Thale Noi non-hunting area

DATA AND METHODOLOGY

Research Data

The data used in this study is the digital data of THEOS satellite image with the multi-spectral system acquired on 10 July 2009; SPOT-5 PAN Sharpened satellite image of 2 meters acquired on 12 April 2006; the color orthophotos image with the scale of 1: 4,000 year in 2002; the relevant database of a GIS ; the primary and secondary information from field trips survey and from other related sectors.

Research Method

1. Collecting and organizing database in the GIS

Collect the primary related information from different sectors i.e. the information of the governing areas, villages, Thale Noi Non-Hunting Area, geographic condition, climate, rainfall quantity, natural water source and irrigation areas, soil resource, land use, transportation route, peat fire, underground water level, etc. The data collection aims to organize a GIS of the Thale Noi Non-Hunting Area.

2. Land use change

The study of the land use change in Thale Noi Non-Hunting Area during 2002 to 2009 is mainly based on the visual interpretation of the satellite images with THEOS satellite image of the multi-spectral system 2009 together with the SPOT-5 PAN Sharpened satellite image 2006 and the aerial photography in 2002. The interpretation needs to depend on the difference of color, texture, size, shape, pattern and the relation with the surrounding items. The area field trips survey is conducted to examine the correctness of the visual interpretation. The adaptation is also conducted and the database in the GIS is organized. After that, the analysis is arranged to analyse the land use change through an overlay method using the ArcGIS 9.3.

3. Risk Factor toward the change of the peatland

It is discovered through the study on the related information with the risk causing the changes within the peatland in Thale Noi Non-Hunting Area that environmental conditions and the area itself are the factors supporting the risk, as followed.

(1) The quantity of the rainfall: the statistic of the Thai Meteorological Department from 1980 to 2009 shows that the average rainfall per year during the period of less rain which is around February to September is between 540 to 940 millimeter while during the dry season the water source is completely dry and the peat water level is lessen. This gives additional opportunity for people to gain benefit from the area.

(2) The depth of the groundwater level is consistent with the quantity of the rainfall as during the rainy season, the amount of water is high while during the dry season or the less rain period, the water in the peatland is also dry. The information of the water level above the ground and the underground water level in 2010 (Pak Phanang Forest Fire Control Station, 2010) shows that the amount of the above ground water decreases dramatically during April to September which is the period of forest fire, leading to the deteriorating and damaging to the land.

(3) The land where there was a forest fire is consistent with the decreasing underground water level during the dry season. The peatland contains decaying plants and animals and as it has the feature of a grass field, it becomes a source for a peat fire during the dry season. A cause of fire can be natural or humans who aim to destroy the land making it easy for them to invade, claiming it for agricultural purposes.

(4) The land use in the non-hunting area tends to decrease while the agricultural land around the peatland increases especially the oil palm plantation, paddy fields, aqua animal farms as well as animal farms. Moreover, the activity of fishing **,** forest item collecting as well as the collection of sedge for crafting become the major career of the surrounding communities.

(5) Soil properties, the characters of soil around the non-hunting area can be categorized into 4 main groups i.e. lowland soil, upland soil, organic soil and slope complex. Each soil contains its own special characteristics. Most of the lowland soil is use for paddy fields, upland soil is used for orchards and perennial crops, organic soil or peat soil contains high organic substance with high amount of acid to make it good for the low agricultural capability and it needs to be adjusted in order to grow plants. Yet, this organic or peat soil has a special character that can be an advantage, that is, its feature is soft which is suitable for some roots to grow especially the roots of the one-season plants as there is enough water in the ground that plant anxiety is not found among them. At the same time, this soil contains high Cation Exchange Capacity (C.E.C), the ability to collect more nutrients substances that are poured into the soil. Therefore, its lack of the substances is rare. Moreover, there is adsorption of some nutrients substances such as phosphorus. However, lacking of the phosphorus becomes a better issue for the land. With all these advantages, the peatland is somehow beneficial for planting, especially oil palm plantation, only if there is the proper management (The Department of Agriculture, 2009). This shows that soil quality is one of the factors effecting the land change.

(6) The transportation through the construction of roads surrounding the peatland area makes it an easy access to the land which, of course, results in the land change because it is easily damaged. Having the roads into the area can additionally cause the downfall of the eco system.

(7) The more expansion of the communities and villages in the non-hunting area as well as the additional needs for the resource and the agricultural land, especially the land around the peat area, for collecting wild items, fishing, etc. becomes an easy matter for those who reside near the peatland.

(8) The natural water source, the irrigation area, the canal digging are means of getting water drain out of the peatland. If a high quantity of water is out, the amount of water will reduce that subsequently the peatland will become dry and sink, making it convenient for villagers to have easy access to the peatland in using such natural and irrigation water for their plantings.

4. Analysis of the importance of factors used in the study

The priority arrangement for factors used in this study is through an Analytic Hierarchy Process (AHP) developed by Prof. Tomas Saaty, University of Pennsylvania, as it is an effective and popular method in the analytical decision. The process respectively determines a target, criteria, sub-criteria, and alternatives prior to an analysis for the best alternative (Saaty, 1980). The analysis on the comparison and criteria is conducted on pair-wise, based on each set criteria until all of the criterion are completed. In order to identify the best criteria, the consistency score is used to prioritize for the best alternatives. AHP can be adapted for the analysis of the land being at risk for change in Thale Noi Non-Hunting Area by analyzing the priority of factors, determining the weighing up value and hierarchy value of the factor used as the main hierarchy and sub-hierarchy until it reaches the required alternative. The data of each factor is compared in pair for its significance through a construction of the matrix table comparing the data used in decision, as the following table 1.

Table 1: weighing the value for the significance of data layers used in an analysis of the risk for change of the peatland in Thale Noi non-hunting area.

Data layer	Rainfall during a less rain period	Ground water level	Area of peat fire	Land use	Soil properties	Community/ village	Transportation routes	Natural water source and irrigation area	Total	Weighing value	Percentage
Rainfall during a less rain period	0.36	0.58	0.37	0.28	0.30	0.20	0.20	0.08	2.37	0.30	30.00
Ground water level	0.12	0.19	0.37	0.28	0.30	0.20	0.20	0.19	1.85	0.23	23.00
Area of peat fire	0.12	0.06	0.12	0.17	0.30	0.12	0.14	0.19	1.23	0.15	15.00
Land use	0.07	0.04	0.02	0.17	0.06	0.29	0.20	0.14	0.99	0.12	12.00
Soil properties	0.07	0.04	0.04	0.06	0.02	0.12	0.14	0.08	0.58	0.07	7.00
Community/ village	0.07	0.04	0.04	0.02	0.01	0.04	0.09	0.14	0.43	0.05	6.00
Transportation routes	0.05	0.03	0.02	0.01	0.01	0.01	0.03	0.14	0.30	0.04	4.00
Natural water source and irrigation area	0.12	0.03	0.02	0.02	0.01	0.01	0.01	0.03	0.24	0.03	3.00
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	8.00	1.00	100.00

Analysis of Consistency Ratio (CR)

This is a test to know the result of the comparison of factors used in this study to see whether it is consistent or correlated. The CR is calculated with the following steps.

Step 1: Calculation of λ_{max} ; this is a result from the calculation of multiplying vertical total of the weighing value of each factor with the horizontal total of an average value of each row. Add all the multiplied results which will be equal to the amount of factors being used to compare. If the outcome is completely consistent, $\lambda_{max} = n$.

Step 2: calculation of Consistency Index (CI); this can be calculated from a formula of

$$CI = (\lambda_{max} - n)/(n-1) \quad (1)$$

Where n = the amount of factors

Step 3: looking for Random Consistency Index (RI); the RI is obtained from the Oak Ridge National Laboratory and the working group. It depends on the matrix table, from 11 to 15 and the outcome is shown in table 4.

Table 2: value of Consistency Ratio (CR) based on the matrix size

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Step 4: Calculation of consistency; this is to look for a comparison ratio between CI obtained from the matrix table and RI obtained from the random selection of the sample from the table. The CR is calculated from the following formula.

CR = CI/RI

The result is CR = 0.00 which is considered perfectly consistent.

5. Determination on weighing value of the main and the sub factors

An analysis on the significance of 8 main factors through the AHP as well as the consistency test of the main factors can determine an important weight of factors used for the analysis of the risk for change of the peatland, showing in table 1. As for the calculation of scores in the hierarchy of the sub-data, the same method is used for the weighing of the main factor starting from the beginning and when a score of all data layers are obtained, the analysis is processed by the geographic GIS.

6. Analysis on the risk for change of the peatland by a GIS.

Data layers of the 8 factors are conducted in the database of the GIS and the weighing value as well as the score of each factor is also conducted, followed by the data processing activity using the technique of the GIS.

RESULTS

The fact that the area of the peatland becomes less and less due to the land use in the Thale Noi Non-Hunting Area while agricultural land, especially oil palm plantation keeps extending shows in the study of the changes during 2003 and 2009 that the land size reduces to 7,091,.08 rai. The land is also changed to a non-productive area, marchland, oil palm plantation, fish-shrimp farm, and paddy field. The consideration of the 8 factors toward the changes of the peatland include (a) quantity of rainfall (b) depth of the groundwater level during the dry season (c) the peatland having peat fire during the dry season (d) the land use (e) soil properties (f) transportation routes (g) community/village (h) natural and irrigation water source. In order to properly and suitably prioritize the significance of the factors, the AHP is applied. This is the analytical process that helps in making the best alternative. The study reveals that the most important factor or 30% is the quantity of rainfall during the less rain period, respectively followed by 23% on the dept of the ground water level, 15% on the peat fire area, 12% on the landuse, 7% on the soil properties, 6% on community/village, 4% on transportation routes, and 3% on natural and irrigation water source. The significance of the priority and weighing value is organized as shown in table 3.

Table 3: Weighing down factors and scores of data used in the study of the area at risk of change in the peatland of Thale Noi Non-Hunting Area, using the method of AHP

Factors used in the study	Sub-factors	Weighing down value	Score value
Average annual rainfall yearly during the less rain period (Feb. – Sept.)	500 mm.	0.30	0.55
	501 – 1,000 mm.		0.26
	> 1000 mm.		0.14
The depth of the ground water level	less than 50 cm.	0.23	0.55
	25-50 cm.		0.26
	0-25 cm.		0.14
Area of peat fire	fire occurring from plant cutting, land cleaning, and burning for farming purposes	0.15	0.55
			0.26
	fire occurring from smuggling of wood		0.14
	fire occurring from animal farming.		0.05
	fire from anonymous causes		
Landuse	marchland, field, bush or field	0.12	0.55
	abandoned peatland		0.26
	perfect peatland		0.14
Soil properties	soil suitable for planting	0.07	0.55
	soil, acid soil, sour soil		0.26

	organic soil		0.14
	wet soil with water all year round		0.05
Transportation routes	less than 500 meter to the peat area	0.04	0.55
	500-1,000meter to the peat area		0.26
	more than 1,000 meter to the peat area		0.14
Community/ village	500 meter to the peat area	0.05	0.55
	500-1,000meter to the peat area		0.26
	more than 1,000 meter to the peat area		0.14
Natural water source, canal and irrigation water	less than 500 meter to the peat area	0.03	0.55
	500-1,000meter to the peat area		0.26
	more than 1,000 meter to the peat area		0.14

Upon analyzing all data of the factors in the GIS, the risk for change can be determined. The findings disclose that the risk area is mostly around the boundary of the agricultural land and the peatland. The peat forest deteriorates while the land sinks. The field normally contains water except during the less rain period when the land becomes dry and the groundwater level dramatically reduces. Because the location is close to the original agricultural land and there are transportation routes that conveniently provide easy access to the place or because it is next to the peatland, the area of peat fire, from both man made and nature, becomes a risky part of the changes. Such risky area is approximately 87.85 square kilometer or 54,911.02 rai or 27.72% of the total peatland in Thale Noi Non-Hunting Area. The land most at risk is found around the upper area, located in KhuanKreng peatland, Kreng Sub-district, Khonhat Sub-district, Nang Long Sub-district of Cha-uat District, Kuan Chalik Sub-district of Hua-Sai District and Karaket Sub-district of Chian Yai District in Nakhon Si Thammarat Province as it covers 66.38 square kilometer or 39,614.81 rai of the peatland. The lower part of the non-hunting area which is located in Phatthalung and Songkhla Provinces shows that the land at risk in Phatthalung is about 15.24 square kilometer or 9,524.65 rai and mostly within the area of Thale Noi Sub-district, Phanang Tung and Laem Tanot of Khuan Khanun District while 9.23 square kilometer or 5,771.56 rai is in Songkhla Province in Ban Khao Sub-district of Ranot District (table 4 – figure 2).

The survey on the land at risk to change obtaining from the data analysis of the GIS shows that most peatland has changed into the peat non-productive forest with bush or fields and bushes, oil palm plantation, and marchland, as shown in figure 2.

Table 4: The land at risk to change in Thale Noi non-hunting area

Province	District	Sub-district	Square kilometer	Rai
Nakhon Si Thammarat			63.38	39,614.81
	Cha-uat	Kreng	46.22	28,889.92
		Khon Hat	3.42	2,137.27
		Nang Long	1.88	1,172.93
	Hua sai	Khuan Chalik	11.69	7,307.32
	Chian Yai	Karaket	0.17	107.37
Phatthalung			15.24	9,524.65
	Khuan Khanun	Thale Noi	12.90	8,060.99
		Phanang Tung	1.45	905.76
		Laem Tanot	0.89	557.9
Songkhla			9.23	5,771.56
	Ranot	Ban Khao	9.23	5,771.56
	Total		87.85	54,911.02

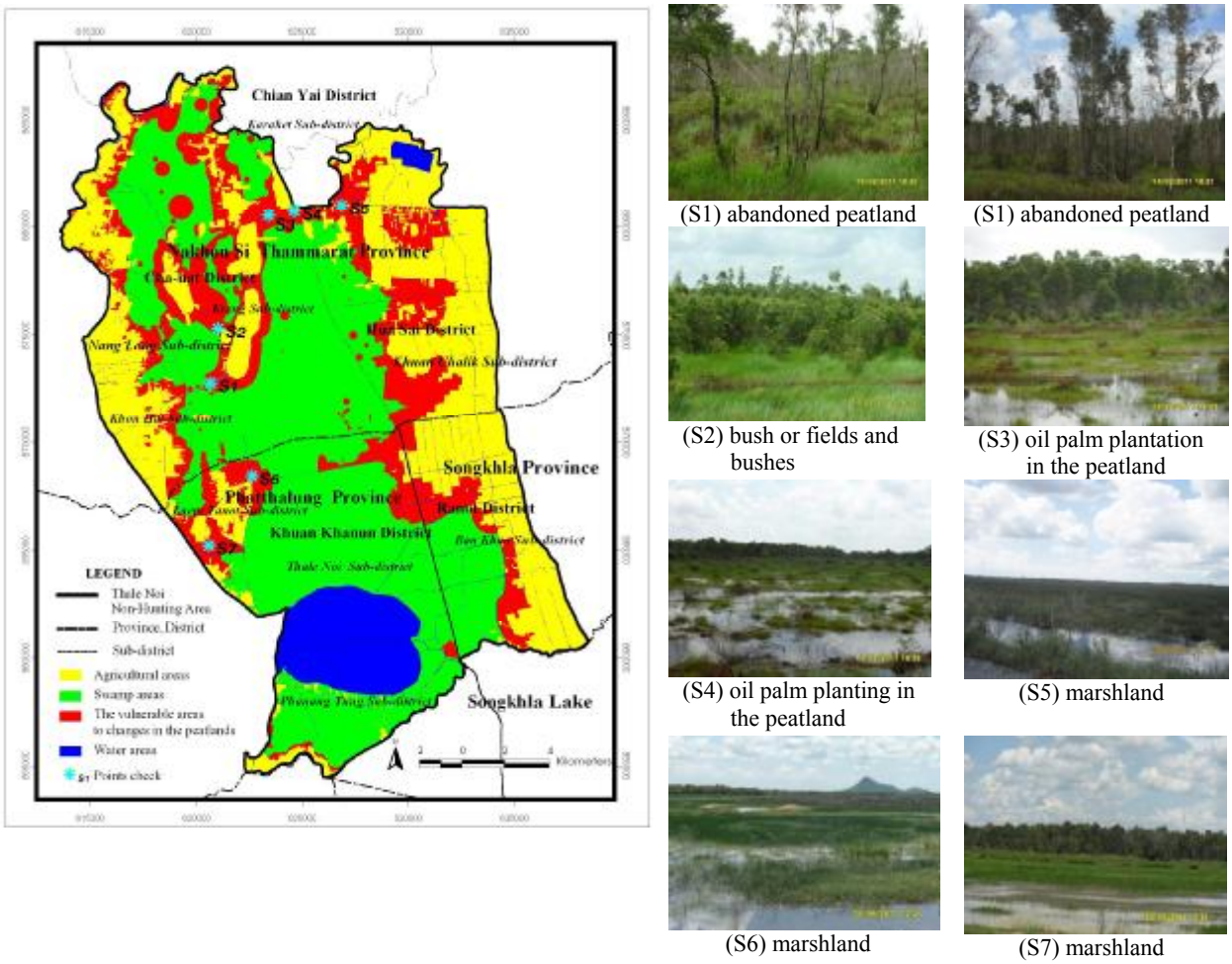

Figure 2: The vulnerable areas to change in Thale Noi Non-Hunting Area.

CONCLUSIONS & RECOMMENDATIONS

The use of the applied Geo-Informatics to look for the vulnerable area, at risk of change within the peatland in Thale Noi wetland through the consideration of the physical factors i.e. the quantity of rainfall, the depth of the groundwater level during the dry season, the land use, the soil properties, the transportation routes, community/village, along with natural water source and irrigation canals through the Analytic Hierarchy Process and the database in the GIS reveals that the factors effecting the change in the peatland can be prioritized as 30% on the quantity of rainfall during the less rain period, respectively followed by 23% on the depth of the groundwater level, 15% on the peat fire area, 12% on the land use, 7% on the soil properties, 6% on community/village, 4% on transportation routes, and 3% on natural and irrigation water source. The analytical result shows the area at vulnerable is mostly around the boundary of the agricultural lands and the peatland, the non-productive peatland and the sinking area while the field always contains water except during the less rain period when the land is dry and the ground water level reduces. The land is at risk of peat fire, both from man made and nature. As the land is next to the original agricultural land and its transportation facility is conveniently providing an easy access, the total area of 87.85 square kilometer or 54,911.02 rai or 27.72% of the peatland in Thale Noi non-hunting is at a high risk of change. The area at risk is found mostly in the upper part of the non-hunting area in Khuan Kreng peatland with 63.38 square kilometer or 39, 614.81 rai while the lower part of the non-hunting area in Phatthalung and Songkhla Provinces, the land at risk is about 24.47 square kilometer or 15,296.21 rai.

This study is only about using the physical factors to analyse the area of the peatland that is vulnerable to change. Therefore, there should be an additional study using others such as economic, social, revenue factors or the turnover from the products of the economic plants especially oil palm, rubber as well as the water animal farming within the area as they are the important factors effecting the area changes. These factors should be analysed in order to construct the most appropriate and complete model.

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REFERENCES:

L.-M. Rebelo, C.M. Finlayson, N. Nagabhatla. 2009. Remote sensing and GIS for wetland inventory, mapping and change analysis. Journal of Environmental Management 90 (May 2009), pp 2144–2153.

Marianna Garf, Laia Ferrer-Mart, Alessandra Bonoli, Simona Tondelli. 2011. Multi-criteria analysis for improving strategic environmental assessment of water programmes. A case study in semi-arid region of Brazil. Journal of Environmental Management 92(March 2011), pp 665-675.

Marine and Coastal Resources Institute (MACORIN). 2009. Report of survey of the Peat fires on 21-22 August 2009 in Khuan Kreng Swamp in the 5- years (2006-2010). Prince of Songkhla University.

Mui-How Phua ,Olaf Conrad, Kamlisa Uni Kamlun, Michael Fischer and Jurgen Bohner. 2005. Multitemporal Fragmentation Analysis of Peat Swanp Forest in the KLIAS PENINSULA, SABAH, Malaysia Using GIS and Remote Sensing Techniques. http://www.ums.edu.my/spta/MGFEP /reports/2018.pdf (accessed April 10, 2012).

Office of Natural Resources and Environmental Policy and Planning (ONEP). 2000. Biodiversity in Thale Noi wetland. Ministry of Natural Resources and Environment. Bangkok, 130 p.

Office of Natural Resources and Environmental Policy and Planning (ONEP). 2011. Ramsar site in Thailand. Ministry of Natural Resources and Environment. http://wetland.onep.go.th/wetlands/frontend/ theme/ramsars_data.php?Lang=0&ID_Wetlands_Main=6. (accessed April 10, 2012).

Pak Phanang Forest Fire Control Station. 2010. The Peat fires in Khuan Kreng Swamp in the 5- years (2006-2010) record. The Department of National Parks.

Saaty, Thomas L. 1980. The analytic hierarchy process: Planning, priority setting, resource allocation. McGraw-Hill International Book Co. (New York and London).

Thai Meteorological Department. 2010. The annual rainfall for provinces of Phatthalung, Songkhla, and Nakhon Si Thammarat in the 30- years (1981-2010) record. Ministry of Information and Communication Technology of Thailand.

The Department of Agriculture. 2009. Cultivation of oil palm in peat soil. http://www.doa.go.th/palm/ linkTechnical/organic%20soil.html. (accessed April 10, 2012).

The Department of National Parks (DNP). 2006. The Thale Noi Non-Hunting Area. http://web3.dnp.go.th/wildlifenew/animConserveDepView.aspx?depId=126. (accessed April 10, 2012).

The Ramsar Convention on Wetlands. 2011. The Ramsar List of Wetlands of International Importance. http://www.ramsar.org/pdf/sitelist.pdf. (accessed April 10, 2012).

The United Nations Framework Convention on Climate Change (UNFCCC). 2005. Greenhouse gas emissions data for 1990 – 2003 submitted to the united nations framework convention on climate change. Key GHG data. United Nations Framework Convention on Climate Change, Bonn, p 157.

WEI Lai, LI Han-lun, LIU Qi, CHEN Jing-yi, CUI Yi-jiao. 2011. Study and implementation of fire sites planning based on GIS and AHP . The 5th Conference on Performance-based Fire and Fire Protection Engineering. Procedia Engineering 11 (2011), pp 486–495.