UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A GIS BASED PEAT SWAMP FOREST FIRE HAZARD MODEL

IWAN SETIAWAN

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**Thesis Submitted to the School of Graduate Studies,
Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of
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Specially dedicated to:

My beloved parents Hj. Siti Kopsah and Maman (almarhum), my brother, sisters, cousin, nephews and my beloved wife Irna Heryani. All of you are my inspiration and my spirit. Thanks for your endless love, concern and for having faith in me.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

DEVELOPMENT OF A GIS-BASED PEAT SWAMP FOREST FIRE HAZARD MODEL

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November 2007

Chairman : Associate Professor Ahmad Rodzi Mahmud, PhD

Faculty : Engineering

A GIS-Based peat swamp forest fire hazard model that integrated AHP process and GIS analysis was developed. A GIS-grid based fire vulnerability map was thus produced for Pekan, Pahang. High correlations (100%) were observed between fire vulnerability zone map that derived from the model with the hotspot distribution locations processed from NOAA satellite data in August 2002 and actual fire spot location recorded by Pahang State Forestry Department in 1997.

The model was tested for fire vulnerability zone using recorded actual fire spot location and NOAA hotspot locations where all of the fire spots locations whether from Pahang State Forestry Department or NOAA hotspots data are located in high and very high vulnerability zone that extracted from the model. The accuracies of maps that derived from the model were verified using hotspot location data extracted from NOAA satellite published by MACRES in August 2002 and actual fire spot locations published by Pahang

State Forestry Department. The verification results showed an accuracy of 100%.

Arc View Dialog Designer to design Arc View Graphical User Interfaces is used for the development of a software tool to run the model in GIS environment. Extensive Avenue programming scripts were written to provide additional capabilities in the development of these interfaces to meet the full complement of operational software considering various user requirements. The software developed not only have user friendly step by step operations to deliver the fire vulnerability mapping but also allows authorized users to edit, add or modify parameters whenever necessary.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBINAAN MODEL BAHAYA KEBAKARAN HUTAN PAYA GAMBUT BERASASKAN SISTEM MAKLUMAT GEOGRAFI

Oleh

IWAN SETIAWAN

November 2007

Pengerusi : Profesor Madya Ahmad Rodzi Mahmud, PhD

Fakulti : Kejuruteraan

Model bahaya kebakaran untuk hutan paya gambut yang berasakan sistem maklumat geografis yang diperolehi dengan mengintegrasikan kaidah AHP dan analisis GIS telahpun dibina. Peta bahaya kebakaran telah dihasilkan untuk kawasan Pekan, Pahang. Kaitan yang tinggi (100%) telah diamati untuk peta bahaya kebakaran yang dihasilkan daripada model yang dibina dengan lokasi hotspot yang diproses daripada satelit NOAA pada Ogos 2002 dan lokasi titik kebakaran yang sebenar yang dicatat oleh Jabatan Hutan Negeri Pahang pada tahun 1997.

Model telahpun diuji untuk zon bahaya kebakaran menggunakan lokasi titik kebakaran yang sebenar dan lokasi hotspot NOAA dimana semua lokasi titik kebakaran tersebut samaada lokasi titik kebakaran sebenar dari Jabatan Hutan Negeri Pahang ataupun hotspot NOAA terletak di dalam kawasan bahaya kebakaran yang tinggi dan sangat tinggi yang diperolehi dari model. Akurasi peta yang diperolehi dari model telahpun divalidasi dengan menggunakan lokasi hotspot yang diproses daripada satelit NOAA pada

Ogos 2002 dan lokasi titik kebakaran yang sebenar yang dicatat oleh Jabatan Hutan Negeri Pahang pada tahun 1997. Hasil verifikasi menunjukan 100% akurasi.

Kajian ini telah menggunakan pereka dialog Arc View untuk merekabentuk antara muka pengguna grafik Arc View dalam usaha membina satu alat perisian yang dapat mengoperasikan model dalam persekitaran GIS. Skrip pemograman Avenue telah ditulis untuk menyediakan keupayaan-keupayaan tambahan dalam pembinaan antarmuka sistim ini untuk memenuhi kelengkapan satu perisian yang dapat digunakan dengan mempertimbangkan pelbagai keperluan pengguna. Perisian ini telah dibina bukan sahaja memiliki langkah demi langkah yang mesra pengguna dalam mengoperasikannya bagi menghasilkan peta kerentanan kebakaran, tetapi juga membolehkan pengguna-pengguna untuk menyunting, menambah atau mengubahsuai parameter apabila diperlukan.

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Modeling Laboratory, Institute of Advanced Techology (ITMA), thank for the facility, to my geomatic-laboratory mate, UPM Indonesian Student Association friends (PPI UPM), my housemate, all my relatives and friends, thank you very much.

I certify that an Examination Committee has met on 20th November 2007 to conduct the final examination of Iwan Setiawan on his Doctor of Philosophy thesis entitled "Development of a GIS Based Peat swamp Forest Fire Hazard Model" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the degree of Doctor of Philosophy.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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IWAN SETIAWAN

Date: 14 January 2008

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LIST OF ABBREVIATIONS

3D	Three Dimensional
AHP	Analytical Hierarchy Process
AIT	Asian Institute of Technology
API	Air pollution Index
ASL	Above Sea Level
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR	Advanced Very High Resolution Radiometer
BLM	Bureau of Land Management
BSA	Bivariate Statistical Analyses
CI	Consistency Index
CLC	CORINE Land Cover
CM	Computer Modeling
CO_2	Carbon Dioxide
CR	Consistency Ratio
DEM	Digital Elevation Model
DG JRC	Directorate General Joint Research Centre
DOA	Department of Agriculture
DOE	Department of Environment
DRASTIC	Depth to Water Table Recharge Aquifer media Soil Media Topography (slope),Impact of Vadose Zone media, (Aquifer Hydraulic) Conductivity
DSS	Decision Support System
EFFIS	European Forest Fire Information System

EFFRFS	European Forest Fire Risk Forecasting System
ENSO	El-Nino Southern Oscilation
ENVI	The Environment for Visualizing Images
ERS	European Remote Sensing Satellite
EU	European Union
FICC	Federal Interagency Coordinating Committee
FRAMES	Fire Research and Management Exchange System
FRD	Fire and Rescue Department
FRI	Fire Risk Index
GIS	Geographic Information System
GIS TreC	GIS Training and Research Center
GMS	Geostationary Meteorological Satellite
GPS	Global Positioning System
GUI	Graphic User Interface
HCWs	Human-caused wildfires
HRI	Human risk index
ISU	Idaho State University's
ITTO	International Timber Trade Organization
JUPEM	Malaysian Survey Department
Landsat	Land Satellite
MACRES	Malaysian Center for Remote Sensing
MCDA	Multicriteria Decision Analysis
MERIS	Medium Resolution Imaging Spectrometer
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index

NIR	Near-infrared
NOAA	National Oceanic and Atmospheric Administration
PSF	Peat Swam Forest
RERAP	Rare Event Risk Assessment Program
RI	Random Index
RS	Remote Sensing
SAR	Synthetic Aperture Radar
SAW	Simple Additive Weighting
SPOT	Syst`eme Probatoire d'Observation de la Terre (satellite)
SWIR	Short-wave Infrared
SWVI	Short-wave-based Vegetation Index
TI	Topography Index
TIN	Triangle Irregular Network
TM	Thematic Mapper
USDA	United State Department of Agriculture
USRD	Upper Snake River District
VBA	Visual Basic Application
VGT	SPOT VEGETATION

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, the world has been fraught with several large scale forest fires occurrences that have caused severe loss of lives, properties and ecosystems. Fire hazards are the scourge of modern civilization as its destruction is not only large scale but also hardly reversible in terms of ecological and economical damages. Wildfires are annual occurrences affecting millions of hectares of forests and bio-resources worldwide. For instance, the Eurasian Boreal Zone has encountered approximately 10 million hectares of burnt forests annually (Johansen 2005). The damage on timber production, the environment, infrastructure and human lives, caused by these fires, has been proportional to the size of the burnt area. In North America, there have been about 100,000 forest fire occurrences annually resulting in some 4 million hectares of burnt areas each year. The corresponding loss of annual timber production amounted to about USD 5 billions (Johansen 2005). In many cases, the total cost, that includes rehabilitation, is several magnitudes higher than the timber value. In addition the impact of the associated release of greenhouse gases and combustion products on the ozone layer and the ecosystem cannot be easily estimated.

Although fire hazards cannot be avoided totally, they can be studied in the spatial domain for better preparedness and mitigation. It is vital that fire hazard maps be generated to study the spatial distribution of the hazards enabling more effective utilization of limited resources to address the forest fire problems in a more balanced manner. Fatal damage by forest fire can also be reduced significantly if there are reliable predictions and rapid provisions against forest fires.

Geographic Information System (GIS), in combination with related technologies such as remote sensing (RS) and computer modeling (CM), are being used increasingly in all aspects of wild land fire management. GIS has also gained wide acceptance as a revolutionary tool for natural resources and disaster management. Many research projects have developed site specific wildfire hazard models based on physiographic and environmental factors that influence wildfire (Pew and Larsen 2001; Vakalis *et al.*, 2004; Sifakis *et al.*, 2004). Identifying susceptible areas with high probabilities of burning occurrences has been an important component of fire management planning (Jaiswal *et al.*, 2002; Pradhan and Arshad 2004). The development of GIS with spatial modeling capability has greatly enhanced this planning process, enabling managers to map and analyze variables contributing to fire occurrences across large unique geographic units.

GIS technology has tools for visualization of fire regimes, which can be queried in different ways to extract useful information for analysis of what if scenarios. A GIS is also capable of integrating various sources of information