Mapping and Analysis of Forest and Land Fire Potential Using Geospatial Technology and Mathematical Modeling

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Abstract. Forest and land fire can cause negative implications for forest ecosystems, biodiversity, air quality and soil structure. However, the implications involved can be minimized through effective disaster management system. Effective disaster management mechanisms can be developed through appropriate early warning system as well as an efficient delivery system. This study tried to focus on two aspects, namely by mapping the potential of forest fire and land as well as the delivery of information to users through WebGIS application. Geospatial technology and mathematical modeling used in this study for identifying, classifying and mapping the potential area for burning. Mathematical models used is the Analytical Hierarchy Process (AHP), while Geospatial technologies involved include remote sensing, Geographic Information System (GIS) and digital field data collection. The entire Selangor state was chosen as our study area based on a number of cases have been reported over the last two decades. AHP modeling to assess the comparison between the three main criteria of fuel, topography and human factors design. Contributions of experts directly involved in forest fire fighting operations and land comprising officials from the Fire and Rescue Department Malaysia also evaluated in this model. The study found that about 32.83 square kilometers of the total area of Selangor state are the extreme potential for fire. Extreme potential areas identified are in Bestari Jaya and Kuala Langat High Ulu. Continuity of information and terrestrial forest fire potential was displayed in WebGIS applications on the internet. Display information through WebGIS applications is a better approach to help the decision-making process at a high level of confidence and approximate real conditions. Agencies involved in disaster management such as Jawatankuasa Pengurusan Dan Bantuan Bencana (JPBB) of District, State and the National under the National Security Division and the Fire and Rescue Department Malaysia can use the end result of this study in preparation for the land and forest fires in the future.

1. Introduction

Land and forest fires in tropical ecosystems are the major environmental problem in Southeast Asia. Forest fires in Southeast Asia happen due to the direct or indirect activities. The cause is usually directly related to human activity that intentionally or unintentionally burn, as well as agents that lead to a fire. Conducted open burning techniques to meet the needs of agriculture, farming, housing construction and commercial center is an example of direct cause. In addition, human activities and negligence involving the use of fire such as throwing cigarette butts in the forest, camping, hunting, fishing and other contribute to the cause directly. Indirect causes of forest fires are as meteorological factors. Climate and weather factors control when a forest fire occurs, in addition to being able to control the frequency. Dryness and moisture are the main parameters related to forest fires. During the months of May to September, Peninsular Malaysia experienced the Southwest Monsoon, where dry

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weather conditions accompanied by wind. This condition could be one factor beside others (human negligence, forest clearing for agriculture, etc.) that making fire spread and more difficult to control.Potential areas for burns capable identified with precision and accuracy is through mapping [1]. Geospatial technology consisting of the integration of remote sensing technology, Geographic Information System (GIS) and digital data collection, enhanced with the use of mathematical modeling Analytical Hierarchy Process (AHP). Then, the information potential of fire is displayed and presented to the user as a Disaster Management Committee, the National Security Council and the Fire and Rescue Department Malaysia through WebGIS application.

2. Study area

The study was carried out in a fire-prone areas. The chosen study area is the entire state of Selangor, Malaysia. Selangor is located in the West Coast of Peninsular Malaysia. Selangor has an area of 796.084 hectares, consists of 9 districts and 55 parishes. Land use and land cover in Selangor are peat swamp forest, forest plantations, forest land, oil palm, paddy, rubber, coffee, cocoa, coconut, grass, old mines, open space, rural areas and urban areas. Selangor has a uniform temperature which is in the range between 21 ° C to 32 ° C, high humidity and abundant rainfall with annual rainfall, about 2.670 mm. 181.502 hectares or 23% of Selangor state is composed of peat and mineral soil remaining. Some of the locations that have high frequencies of forest fires identified is in the Bestari Jaya, Ulu Tinggi , Kuala Kubu Bharu, Kuala Langat, Banting, Dengkil and Sepang.

3. Methodology

The methodology accounts for the observed GPS field data, satellite image processing, GIS database development, the use of mathematical models and the development of WebGIS application. A flowchart of the methodology of this study is shown in Figure 1.

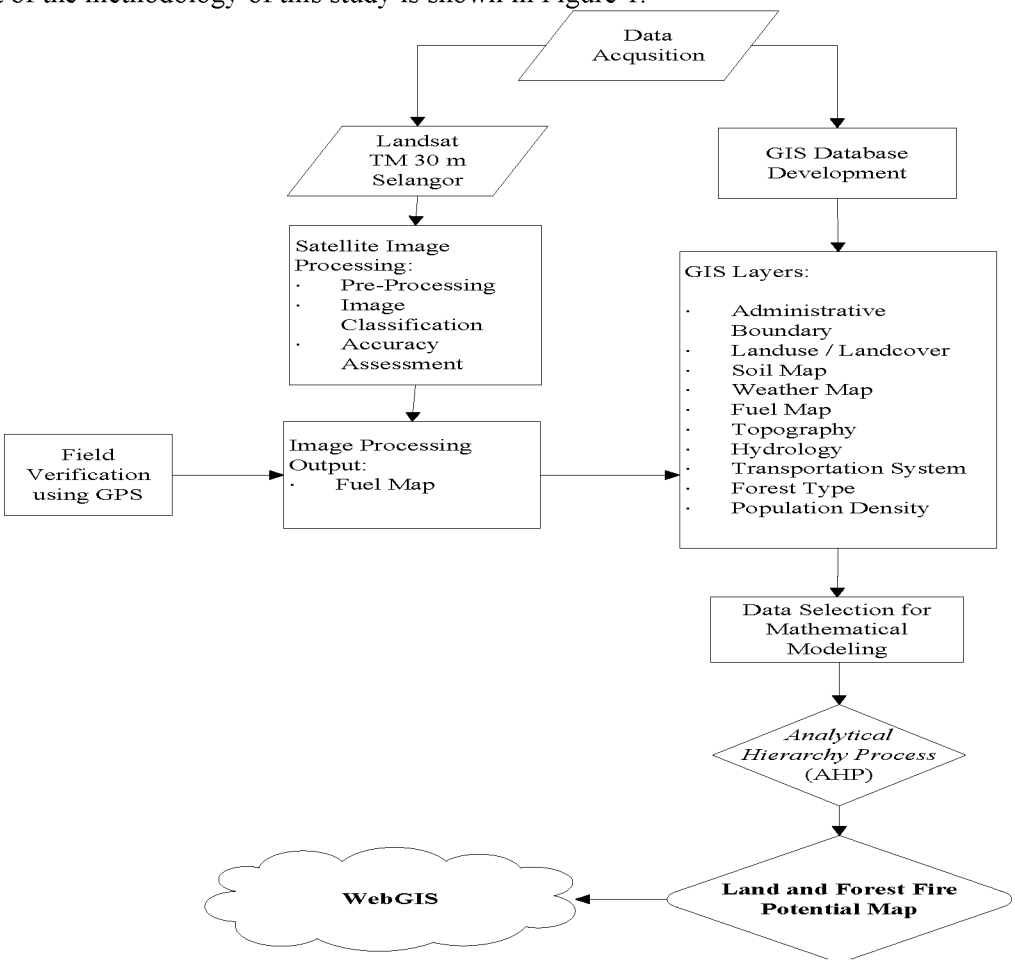

Figure 1. Flowchart of the methodology

3.1. Satellite image processing

Satellite image processing is carried out to produce the fuel map. Satellite images used are Landsat-7 ETM. Satellite image processing involves pre-processing and image classification. Geometry Correction and Atmospheric Correction are two methods that have been carried out for the preprocessing stage.Eight types of fuel class such as grasses, slash, open forest, closed forest, oil palm, rubber and other agriculture including non-fuel material was classified and the result of the classification of fuel material combined (union) to map of soil types consist of two main classes that are mineral soil and peat soil to form a fuel map that contains the class of sixteen types such as grasses on mineral soils, grasses on peat soil, closed forest on mineral soil, close forest on peat soil, open forest on mineral soil, open forest on peat soil, slash on mineral soil, slash on peat soil, coconut palm on mineral soil, oil palm on peat soil, rubber on the mineral soil, rubber on peat soil, agriculture on mineral soil, agriculture on peat soil, fuel material on mineral soil and non-fuel material on peat soil. Map of fuel material is shown through Figure 2. Comparison map generated through an image classification process the GPS data observations give overall accuracy of 75 percent. While in remains error is 0.25, and the error done is 0.01667.

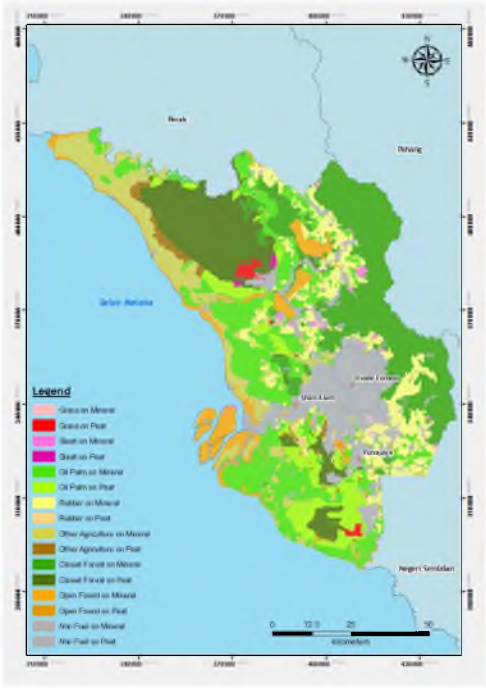

Figure 2. Fuel Map in Selangor.

3.2. GIS database development

GIS database developed to facilitate the process of effectively managing GIS data and strategic planning. This is because the GIS data is not only used as a determining criteria for the potential analysis of forest fire, but it is also used as ancillary data to help users decide WebGIS application. GIS database development will expedite the process of data analysis as well as faster data access in the WebGIS application.

3.3. Mathematical model

The weight value for each criteria form the basis in determining the level of importance of the criteria. If the value of weights for a given criteria is higher, then, it is the most important criteria . Various methods can be used in determining the weights of criteria. Among the methods used are as restructuring the position (ranking), the provision of value (rank), the comparison between the criteria (pairwise Comparison) and the trade-off [2]. In this study, questionnaires were conducted to obtain an evaluation against a criterion that can be the potential for forest fires from the specialist. The

specialist assessment of each criteria for potential forest fire and land is made up of elected officials form Fire and Rescue Department Malaysia, namely:

I. Tuan Borhan Bin Madon, Penolong Kanan Penguasa Bomba, Bahagian Operasi, Ibu Pejabat Jabatan Bomba dan Penyelamat Malaysia, Putrajaya
II. En. Wan Zakaria Bin Wan Busu, Pegawai Bomba, Bahagian Operasi, Jabatan Bomba dan Penyelamat Negeri Selangor, Shah Alam
III. En. Mohd Jasni Bin Somidi, Pegawai Penjaga, Balai Bomba Bukit Jelutong, Shah Alam

Analytical Hierarchy Process (AHP) is a method used to produce the weight value, after each criteria evaluated by a specialist to determine the potential of forest fire and land. The most consistent evaluation (lowest degree) will be used as a potential determinant of forest fire and land in the state. Once the weights obtained by AHP, the output or result can be interpreted spatially connected using the GIS approach. Each raster data are multiplied by the weight value obtained from the method of AHP, then added all raster data involved in order to generate the final output. Final output is based on the goals or objectives to be achieved in the AHP method. The AHP structure formation begins with the objectives to be achieved, the criteria and sub-criteria. This is illustrated in Figure 3 which shows the hierarchical structure of the potential of forest fire and land.

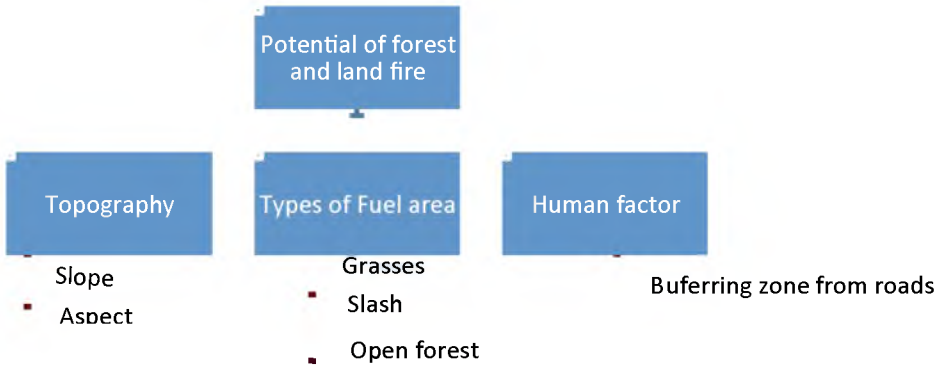

Figure 3. A hierarchical structure for potential forest and land fire.

3.4. WebGIS development

WebGIS is used to disseminate information from the analysis of forest fire potential to the user. Information dissemination and achievement levels are very wide, it is based on the technology of the Internet without boundaries. The focus of WebGIS for this study include potential map of forest fire and land, the administrative boundary data layer states, counties, cities and parishes in Selangor, land use and land cover, soil type, fuel, temperature, rainfall, relative humidity, elevation models digital (DEM), slope data and the surface data, streams and drainage systems, roads, forest type and population density.

4. Result and analysis

Based on the analysis of land and forest fire potential, 32.83 square kilometers of the total area of the state are the extreme potential for fire was identified. Areas identified were the Bestari Jaya that is in Raja Muda Musa Forest Reserve and Agrotech, Mukim Ulu Tinggi and North and South of Kuala Langat Forest Reserve. Type of land covering an area of extreme fire rate is mostly peat soil . Forest fires also occurred several times (based validation hotspots) occurred this area and clearly shows that the nature of the fuel material is flammable and dries quickly. It consists of grasses and forest waste. High potential areas of fire covering 244.32 square kilometers, or 3 percent of the acreage of. Areas with high potential for fire is fueled by the factor of fuel material on the peat soil. In addition, the human factors of accessibility to the road against a fuel material is the impetus for the high potential of fire. This can be identified in several locations in the Elite Highway, Bandar Saujana Putra, Bestari Jaya roads, Dengkil and Sepang. Based on the map of potential forest fire and land, the area is in Batang Kali and Ulu Yam. Almost 65 percent of the total size of Selangor has lower potential and do not have potential for forest fire occurred. The area is guaranteed safe from fire as the main factors are

non-fuel materials. Classification from the high potential forest fire until the no potential at all is very important in this study. Classification is based on the lowest to the highest value in the summation of each raster data that represents the criteria and sub-criteria involved.

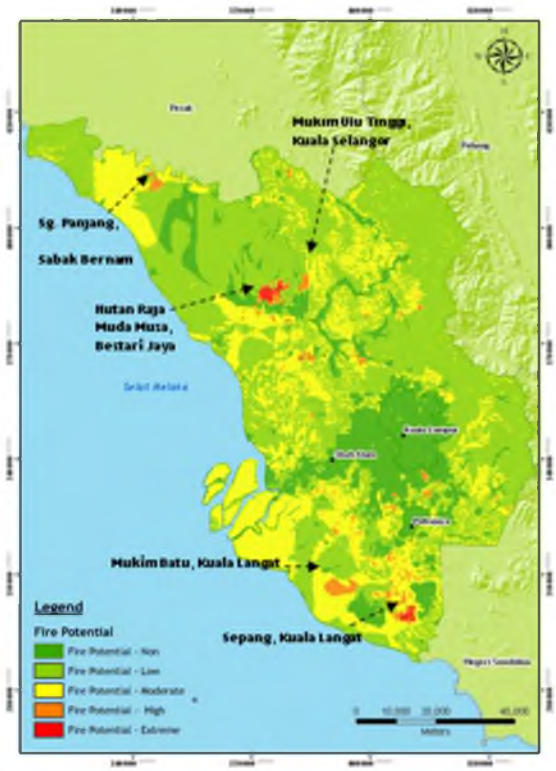

Figure 4. Map of potential forest and land fire in Selangor

The final potential of land and forest fire map is published on WebGIS application. WebGIS is equipped with spatial information such as maps of administrative boundaries, fuel, land use, soil type and other spatial data stored in the GIS database was constructed. It also comes with features that are currently available GIS analysis as buffering, spatial queries and distance measurements. This facilities will help operational managers or users to make decisions with accurate and precise, almost equal to the actual situation. Sample display of WebGIS has produced, as shown in Figure 5.

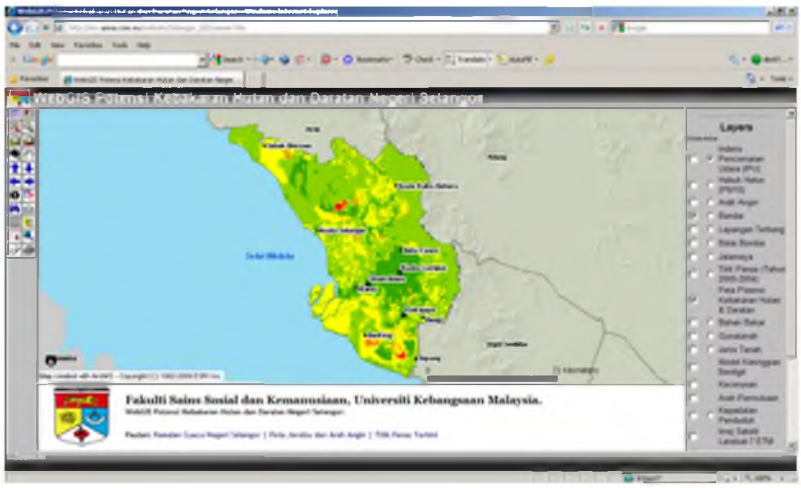

Figure 1. The potential of land and forest fire map in WebGIS application

5. Summary

This study has demonstrated the development of geospatial technology and WebGIS in helping disaster management and operators face the threat of forest fires and land. In accordance with these developments, the technology has been used in collecting, evaluating and disseminating data and information that is important for the operation of the land and forest fires in terms of monitoring, detection, enforcement and prevention.

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