Spatial Technology for Risk Management

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Keywords: spatial technology, risk management, disaster, flood, forest fire, landslide

SUMMARY

Spatial information technology is a tool that supports for researching natural disaster risk management programs of flooding, fire forest, and landslides. Flooding disaster management provides a quick response to the rapid onset of disaster by Flood Early Warning System and Flood Monitoring and Mitigation, hence the use of NOAA AVHRR and GMS data in order to better mitigate and manage disasters. Developing a peat swamp forest fire disaster management system, improve the existing method of forest fire hazard assessment and dynamic distribution resource. The study integrates high spatial resolution remote sensor data with Geographyical Information System (GIS) data and multi criteria analysis for developing a methodology to model peat swamp forest fire disaster risk, to assist in providing decision support systems for emergency operations and prevention action. Landslide is the result of wide variety of processes, which included geological, geomorphological, and meteorological factors such as lithology, structure, soil cover, slope aspect, slope inclination, elevation, and rainfall. The spatial technology has the ability to assessment, estimation of landslide hazard region by creating thematic maps and overlapping them to produce final hazard map, that leads to instability in the region by classifying the region to three categories: low, medium, and high risk.

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1. INTRODUCTION

Disaster risk management is the systematic management of administrative decisions, organisation, operational skills and abilities to implement policies, strategies and coping capacities of the society or individuals to lessen the impacts of natural and related environmental and technological hazards (Strand 2003). Spatial technology make easier to explore the world and the neighborhood you live in, share knowledge, find opportunities, and make informed decisions. The development of spatial technologies has been driven by the need for better decision making. Early innovators were motivated by the belief that experts in a wide variety of fields could make better decisions if they had better tools for analyzing and visualizing geographic data (Harrison, 2004).

Term "risk" is often confused with "hazard". Risk is the probability or chance that hazard posed. The Hazard is inescapable part of life (Smith 1996). The hazard is the potential; disaster is the actual event (Drabek 1997). Disaster is the result of a hazard impacting a community (Blanchard, 1999). Disaster is a source of danger whose evaluation encompasses three elements; risk of personal harm, risk of property, risk of environmental damage and the acceptability of the level degree of risk (Kovach 1995 and Smith 1996). Natural or environmental disaster have the advantages of including both natural and man-made dimensions, such as lithosphere disasters (landslide, subsidence, earthquake), atmospheric disasters (rain, lighting, temperature), hydrosphere disasters (flooding, coastal erosion), biologic disasters (forest fires and wildfire), and technological disasters (oil spills, transport accidents, and failures of constructions), which causes substantial damage/pollute or injury/death to civilian property or persons. The risk is the probability or chance that the hazard posed. Consequently, it can be reduced by primarily preparing a suitable risk management. Risk management is important in Protecting community and environment safety, providing better information to make decisions, enabling better asset management and monitory, and improving the perception of community for risks.

The goal of this paper is to dealing with the natural hazard (flood, forest fire, and landslide) to reduce the impacts that can be taken prior to their occurrence, which adapts spatial information technologies to support increased coordination among multiple programs of risk management by examining the application of these technologies to the task of identifying, analyzing, assessing, treating and monitoring.

2. RISK AND RISK MANAGEMENT

Risk arises out of uncertainty. It is an inherent part of existence and is the chance of something happening as a result of a hazard or a disaster which will impact on community and environment. It is measured in terms of the likelihood of it happening and the consequences if it does happen that be tried to reduce the likelihood of risk effecting on community. The risk is the probability or chance that the hazard posed. Thus, it can be minimised by initially preparing a suitable risk management.

Risk Management is a process consisting of well-defined steps which, when taken in sequence, support better decision making by contributing to a greater insight into risks and their impacts (Sai Global 2003). It is as much about identifying opportunities as it is about used to avoid, reduce or control risks. The first step in the risk management process is focused on the environment to establish the boundaries in which risks must be managed and guide decisions on managing risks, and develop risk evaluation criteria. The second step involves identifying the risks which arise from aspects of the environment that will be established from previous step to develop a complete inventory of the risks and what each involves, by selecting suitable techniques to identify potential risks, examining sources of possible risks, pose a major threat to community. Assess and analyse the impact of the risks represent the third step, which involves deciding on the relationship between the likelihood (frequency or probability) and the consequences (the impacts) of the risks that be identified. The level of risk should be analysed in relation to what are currently doing to control that risk. Control measures decrease the level of risk, but there may be sufficient risk remaining for the risk to be considered with others. Risk evaluation will be clarified the following as the activity of risk managing and its outcomes, the degree of control over the risk, the potential and actual losses which may arise from the risk, and the benefits and opportunities presented by the risk. the next step is to treat the risks that be decided as unacceptable by identifying the options which could use to treat the risks, selecting the best option in terms of its feasibility and cost effectiveness, preparing a risk treatment plan, and implementing the risk treatment plan.

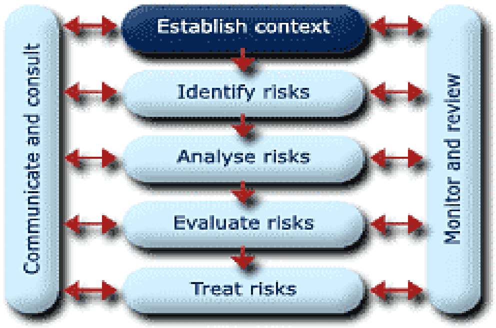

Figure 1: Risk management

Typically, the disaster risk management system addresses the three distinct phases pre-disaster planning i.e. early warning, during disaster activities (=response) and post disaster (includes recovery, relief, rescue and rehabilitation) (Narain, 2003) (Figure 1). The mitigation of the effects of disasters requires relevant information regarding the hazard in real time. Also the possible prediction and monitoring of the disaster requires rapid and continuous data and information generation or gathering. Early warning in the disaster context implies the means by which a potential danger is detected or forecast and an alert issued. There are three abilities, which constitute the basis of early warning. The first, largely technical ability is to identify a potential risk, or the likelihood of occurrence of a hazardous phenomenon that threatens a vulnerable population. The second ability is that of identifying accurately the vulnerability of a population to whom a warning needs to be directed. The third ability, which requires considerable social and cultural awareness, is communication of information to specific recipients about the threat in sufficient time and with a sufficient clarity so that they take action to avert negative consequences. Establishment of a disaster early warning system requires the development of both local and national risk information capabilities and use of relevant technological applications for rapid and improved warnings. Satellites through their continues coverage of the globe, provide essential information that can lead to rapid and effective detection and interpretation of many hazards (Ottichilo 2003).

Disaster estimating is the foundation in urban risk management that the main aim of risk management is to estimate and predict the loss for the areas which possibly suffer from disaster with the help of many means of spatial information technique, as well as to analyze the cost, which is possibly produced in the course of carrying the control schemes for disaster protection into execution. Those historical and real-time information can be been gathered by remote sensing, photogrammtry and aerial photographs for determining zones of slope instability, Earth-Observing Satellite Images for mapping and monitoring of different disasters, Meteo-Satellites for weather conditions and flood hazards prediction and monitoring, Satellite Radar Satellite for hazard monitoring**,** or other methods, then been handled in Geographyical Information System (GIS). It can provide important basis for the selection of the control schemes in each decision-making stage.

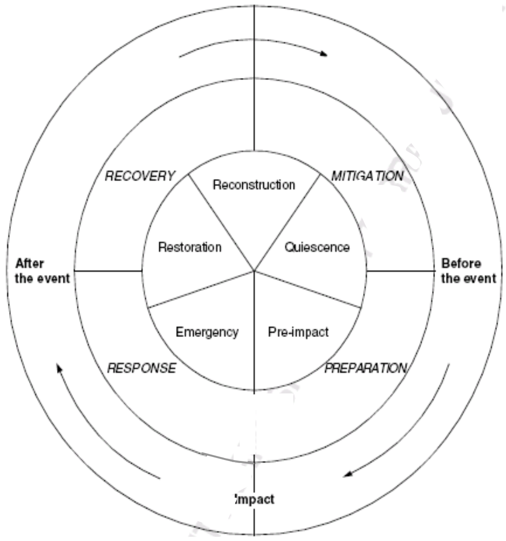

Figure 2: Disaster cycle

3. SPATIAL TECHNOLOGY FOR FLOOD RISK MANAGEMENT

The development of efficient flood management strategies involves a comparative assessments of the potential financial benefit of flood management scenarios by reducing the damaged to property and infrastructure, displacement of communities and general loss of income. Flooding is a natural phenomenon that regularly brings disruption and damage to different parts of world not excluding Malaysia. Floods vary in scale from water running off a saturated hillside to large rivers bursting their banks. The impacts of floods range from waterlogged fields and blocked roads to widespread inundation of houses and commercial property and, occasionally, loss of life. The consequences can be enormous, recent flash floods in Selangor and Kuala Lumpur of Malaysia 2002 and again in 2003 resulted in extensive damage to property to the tune of over 300 million Ringgits (Figure 2).

Figure 2: Flash flood in Malaysia 2003

3.1 Flood Early Warning System

In recent year, the advent of improve computing power and the introduction spatial information technologies has made flood risk management that once seem an difficult task due to the vast quantities of diverse information required a possibility. Remote sensing and

GIS technique can be variously applied in the collection and processing of spatial and non-spatial data for flood risk management. The operational coupling of remotely sensed data with hydrological oriented GIS has become a viable option in particular flood early warning systems. Quantitative precipitation forecasting (QPF) through remote sensing with the integration of hydrological data hydraulic modeling in the bid to implement a fully automated flood simulation and forecasting system is drawing much attention in research circles.

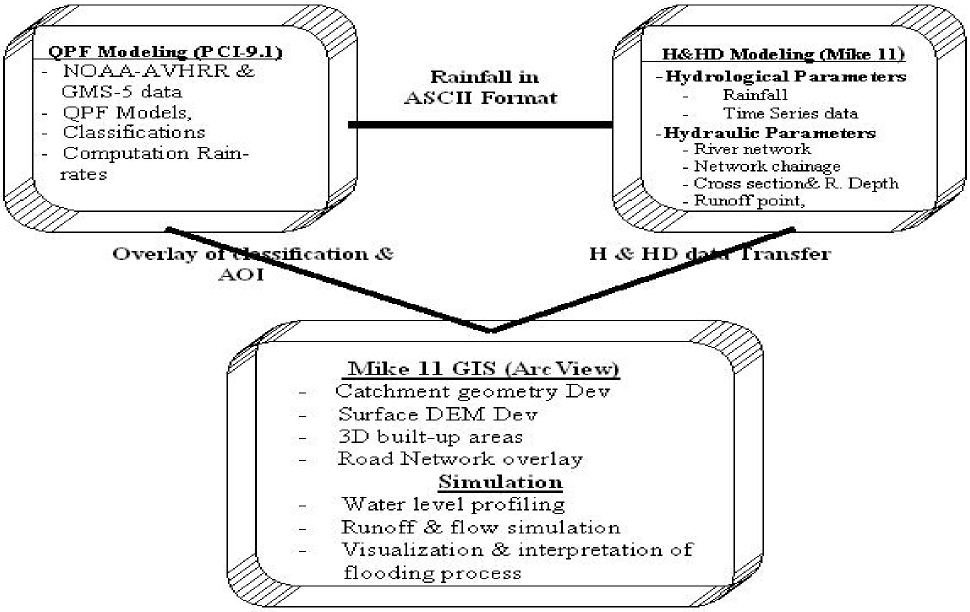

Figure 3: Data and Tools Integration for Flood Early Warning System

Figure 3 describes data and tools integration flood early warning system in the Langat river catchment in Malaysia. Ideally actual rain fall data gathered in real-time should be suitable this, but in other to increase the lag time of possible flood it was important develop methods to estimate and forecast precipitation hence the use NOAA AVHRR and GMS data (Figure 4). The incorporation of Mike 11 hydraulic model together with telemetry rain gauges and flow sensors provide real-time simulation and flood control measures such as reservoir capacity, river flow and levels. The role of the GIS in the outlined framework is multifaceted (Lanza et. al. 1993), being essentially the operational platform for the handling of vast data required and also for the implementation of a fully automated rainfall- runoff and flood modeling. The forecasting systems further provide a The forecasting systems further provide consequently flood mitigation should not only encompass the traditional engineering, socio-community and infrastructure development but also broadly involve an integrated planning and management approach through the enhancement of public administration, watershed management, land use planning and prioritization, not forgetting the control of land degradation and reforestation, and basis for warning local authorities and the affected population of the expected levels and extent of flood inundation, basis for warning local authorities and the affected population of the expected levels and extent of flood inundation.

3.2 Flood Monitoring and Mitigation

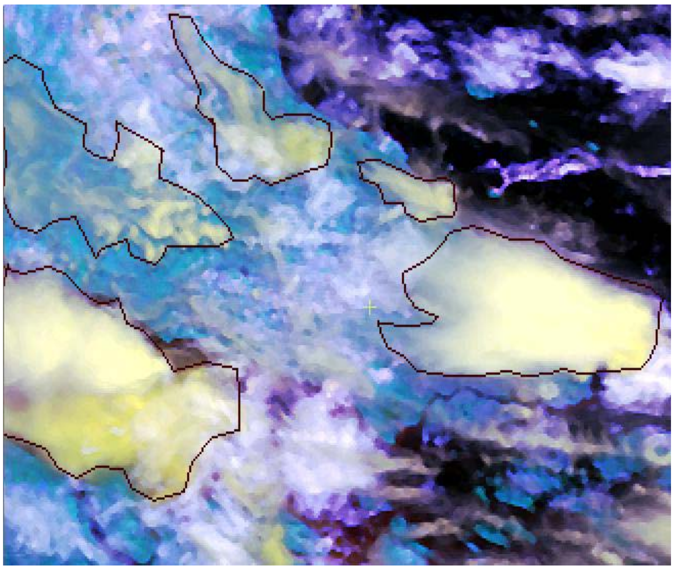

Figure 4. Low cloud clusters on AVHRR over the south of peninsular Malaysia (Billa et al 2003)

The effective planning of flood risk management strategies and preparedness for the safety of communities living in flood prone areas requires knowledge of past floods and the ability to anticipated impending flooding. Generally experts of the agreement that flood risk management strategies should involve: hydrological assessments, monitoring networks and information systems, Flood risk and damage assessment, real-time flood forecasting and operational water management systems, river hydraulics and morphology, and land use and climate change studies.

4. SPATIAL TECHNOLOGY FOR FOREST FIRE MANAGEMENT

Forest fire is defined as an uncontained and freely spreading combustion which consumes the natural fuels of either a forest or a plantation or a grassland or a shifting cultivation area that is, duff litter, grass, dead branch wood, snags, logs, stumps, weeds, brush foliage, and to a limited degree, green trees (Ketpraneet et.al. 1991).

4.1 Fire Hazard Model Early Warning System

A wildfire risk model can serve as an early warning system to predict the severity level of future fire risks which significant for wildfire prevention and fighting strategies. Developing a GIS-based wildfire hazard modeling which aim to identify geographic locations with the highest wildfire hazards and risks. Fire hazard is defined as a fuel condition or state that may result in an undesired wildfire event. Risk is defined as the probability of an event occurring. For example, dense housing within a high wildfire hazard area may have a higher probability or risk burning than home s within a patchy fuel complex (Sampson et al. 1998). In the literature the words hazard and requirement have different meanings. Hazard includes both risk and danger component (risk is associated to prevention and ignition, danger corresponds to spread and fighting actions) (Wybo, et al 1995).

A fire risk model will be developed by combining the point data such as weather data and the surface data such as satellite data. We introduce the fire risk model to the forest fire early detection system which is working at present in order to offer the information that is useful for deciding on the fighting priority in the fire prevention planning in the targeted area. For the disaster mitigation, information of the present condition and prediction of the situation are necessary.

4.2 Fire Hazard Models

Fire hazard model is developed based on Chuvieco and Congalton (1989) that considers the influence of several factors in forest fire. The methodology can be modified for classifying the fire hazard areas assesses for each pixel according to the following variables: Forest species, land use type, elevation, slope, aspect, and distance to roads.
The following is the model to identify the fire risk area based on the fire affecting factors:
P = 0.1 AVI + 0.046 AVII + 0.022 AVIII + 0.010 AVIV + 0.004 AAI + 0.01 AAII + 0.024 AIII + 0.156 VF.I + 0.094 VF.II + 0.078 VF III + 0.062 VF.IV + 0.047 VF.V + 0.039 VF.VI + 0.000 VF.VII + 0.04 DI + 0.014 DII + 0.014 DII + 0.027 DIII + 0.082 DIV + 0.123 DV + 0.004 EI + 0.007 EII + 0.034 EIII + 0.014 EIV

Where:
AV = Distance to roads variable
AA = Distance to rivers variable
VF = Forest species variable
D = Slopes variable
E = Aspect variable
(I…..VII = Subclasses of each variable)
Logistic Regression (Myung-Hee Jo et al.1999)

Zi = 3.754 + 0.231 (slope) + 0.324 (elevation) + 0.165 (aspect) + 0.328 (stream) + 0.195 (forest type) + -0.017 (agricultural pattern) + -0.128 (Urban) + 0.030 (road) + 0.872 (rainfall) + 0.652 (Sunshine) + 0.713 (moisture).

Pi = exp(Zi) / (1 + exp(Zi))

Darmawan Model (2000), all the variable have the same weight
FT + EL + GR + AS + BR
Model 2. Fuel type derived from land use/cover has a weight twice higher than the other variables
20FT + 10 EL + 10 GR + 10 AS + 10 BR
Model 3. Fuel type derived from land use/cover has a weight higher followed by gradient
30 FT + 20 EL + 10 GR + 10 AS + 10 BR

Where FT = Fuel type
EL = Elevation
GR = Gradient
AS = Aspect
BR = Buffer road.

It has been known that a basic factor affecting spread of forest fire as follow: fuel type, fire behavior and human activities (Wirawan, 2000). Therefore three groups of factors were identified: land use/cover related to fuel type, terrain related to fire behavior, and road related to human activities. Castro and Chuveico (1998) divided the factor into Human Risk

Index (HRI) and Topography Index (TI). They included several human activities related to fire risk such as agricultural practices, accessibility for recreational use and proximity to urban areas. Fire risk relative importance of six factors i.e. slope, topography, soils, vegetation, hydrographic and land use, stream and aspect. The potential factors including aspect, elevation, slope, stream, vegetation, which can have an effect on forest fire will be extracted for probability analysis.

Topography affects the amount of solar radiation an area receives. Topography can modify wind speeds and direction and create wind eddies. Important factors associated with topography include Aspect, elevation and steep slopes.

Aspect is the direction the slope faces-its exposure in relation to the sun. Fire condition will vary dramatically according to aspect. Southern exposures receive maximum solar and wind influences, while the northern slopes receive the least. Generally eastern aspects receive early heating from the sun and early slope winds, while western aspects receive late heating and transitional wind flows. Aspect is related to the amount of sunshine. In general, the cases of forest fire occur in area of south more than in the area of north because a southern exposure has higher burning point. Actually, more than 40% of forest fire happened in aspect of south area while doesn't happen in other area.

Slope is critical factor in fire behavior and aspect is clearly related to insolation and air humidity. Typically, in the temperate zones of the Northern Hemisphere, south-facing slopes receive more solar radiation than north-facing slopes. Therefore, south-facing slope are hotter, drier and pose greater fire risks. More than 60% of forest fire happened in between a slope of zero and a slope of twenty degrees and in aspect of south and southern west (Hee jo, et al 2000). 65% cases in entire forest fire occurred in between a slope of zero and 20 degrees. The rate of forest fire decrease remarkably as slope increase (Hee jo, et al 2000). Slope increase fire risk: as surface's slope increase as well.

Elevation influence vegetation compositions, fuel moisture and air humidity. More than 90% cases of forest fire happened at 100m above the sea level. Most these disasters take place in lower area above the sea level. Fire less severe at higher elevation due to higher rainfall. Two factors to consider are (1) elevation above sea level and (2) elevation changes in relation to surrounding topography features. It has been reported that fire behavior trends to be less severe at higher elevation due to high rainfall. Step gradient increased the rate of fire spread because of more efficient convective preheating and ignition, and gradient facing to the east receives more ultraviolet during the day, as consequence east aspect drier faster (e.g. Chuviecio and Congalton, 1989). Terrain (elevation, gradient and aspect) was derived from digital elevation model (DEM).

Stream is regarded as an important role not only to extinguish forest fire but also to provide moisture towards plants. The area far from stream has higher dangerous factors. Hydrographic features help to detain and distinguish fire, by serving as break-lines and water resources. Roads can be immediate factor to forest fire because there are human beings (Hee jo, et al 2000).

Soil types affect the amount of moisture retained in the soil profile. If more moisture is available, the risk of fire is reduced.

Different types of land use must be considered because some areas, such as campgrounds, have greater potential for fire to ignite due to human activities. Vegetation density must also be considered. An area's vegetation must be considered because some vegetative types are more flammable than others are, thereby increasing fire risk.

Higher density, the more fuel there is to burn, thus increasing fire risk. Fuel, which is composed of the amount of precipitation, the humidity of air, the direction of the wind and temperature, is very related to season and time (Hee jo, et al 2000). Wildland fuels are critical elements in many wildlend fire planning and management activities. Fuels represent the organic matter available for fire ignition and combustion, and they represent the one factor relating to fire that humans can control (Rothermel 1972, Albini 1976, Salas and Chuvieco 1994). Fire managers need to spatially describe fuel characteristics across many spatial sacles to aid in fire management decision-making (Mutch et al. 1993, Covington et al. 1994, Ferry et al. 1995, Leenhouts 1998). A spatial description of fuels is fundamental to assessing fire hazard and risk across a landscape so management projects can be prioritized and designed. Accurate, spatially explicit fuels data have become increasingly important as land management agencies embrace prescribe fire as a viable treatment alternative to reduce the potential for severe fires over large land areas.

4.3 Model and System Development

A research is aimed at developing a peat swamp forest fire disaster management system at Pekan District, southern of Pahang, Peninsular Malaysia, which may improve the existing method of forest fire hazard assessment and dynamic resource distribution. The study integrates high spatial resolution remote sensor data with GIS data and multi criteria analysis for developing a methodology to model peat swamp forest fire disaster risk using GIS and user interface with Multi Criteria Analysis (MCA) to verify this model with occurrence fire in the study site, which may assist in providing decision support systems for emergency operations and prevention action (Figure 5).

A mosaic of two scenes Landsat TM image was used for land use classification of this study area using RS software. Slope, elevation and aspect as well road network were derived from digital topographic map. 3D and spatial analysis will be used for classifying and reclassifying factors in a spatial data. Flow chart of the study framework is depicted in Figure 6.
A GIS-based fire hazard model will be applied to determine the severity level of wildfire hazard zone in terms of wildfire vulnerability mapping by assessing the relative importance between wildfire factors and the location of fire ignition. A DEM dataset will be used in order to derive slope and aspect dataset. All of dataset will be converted into grid cell size in Arc View grid format. Multi Criteria Analysis (MCA) will be employed to determine the rank of fire hazard area. The roads network, elevation, slope and aspect were obtained from digital topographic map. The elevation, slope and aspect map was obtained in 2D vector format, and was then converted to 3D, to generate the Digital Terrain Model (DTM). These themes slope elevation, and aspect, will be reclassified using spatial analyst, into four classes

that indicated the hazard value. After the same processes is repeated for the other fire hazard factors, these fire hazard layers can be overlaid onto one final map yielding the Final Fire Hazard map.

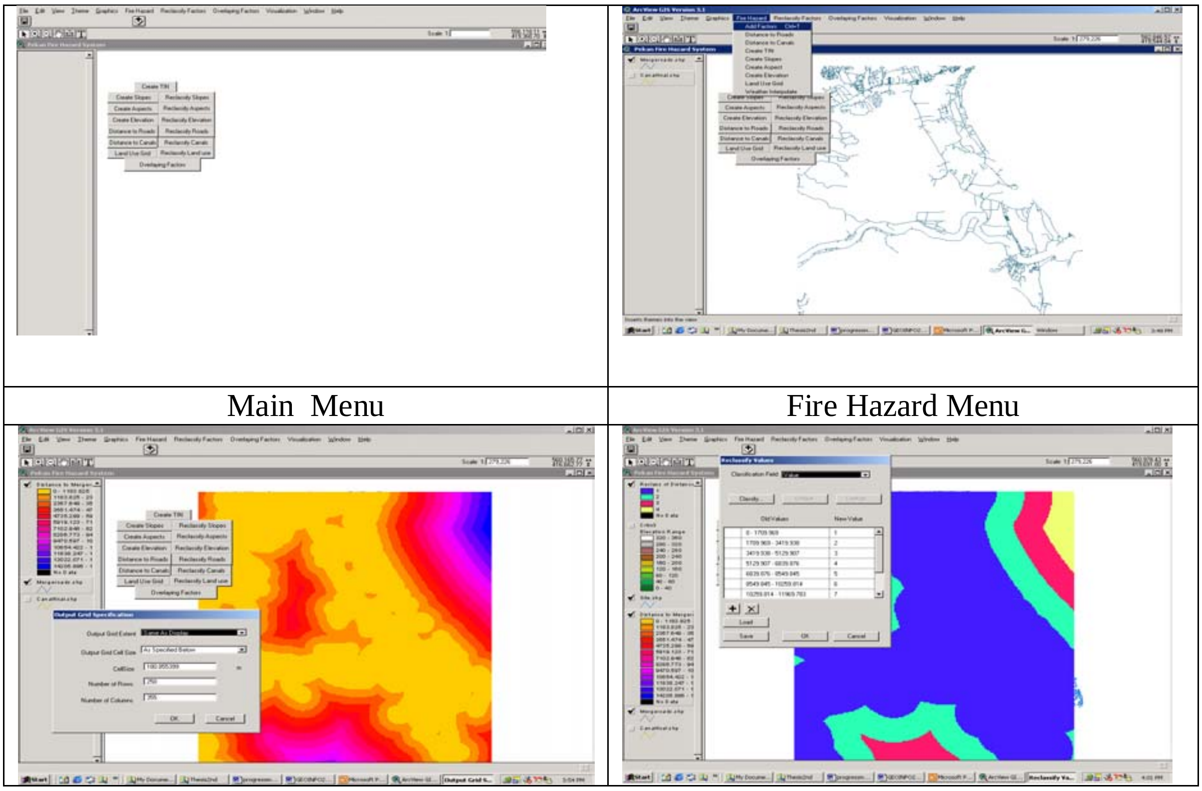

Figure 5: User interface GIS-Grid based forest fire hazard mapping (Setiawan 2004)

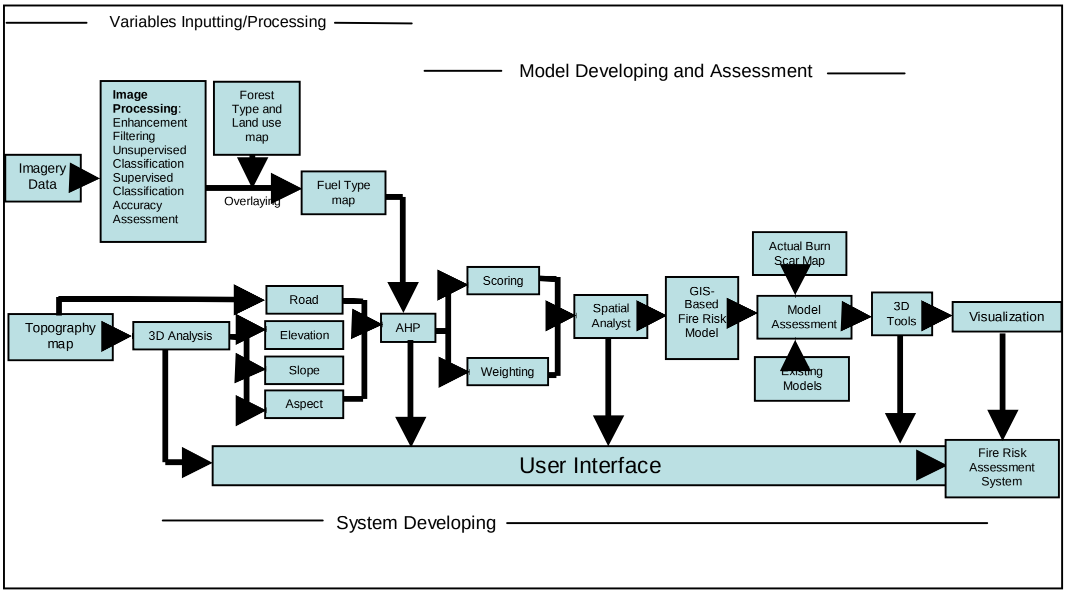

Figure 6: Data and Tools Integration for forest fire operational assessment system.

5. SPATIAL TECHNOLOGY FOR LANDSLIDES RISK MANAGEMENT

Landslides risk management deals with situations that occur prior to, during, and after the landslide in order to reduce or avoid the human, physical and economic losses suffered by individuals, by the society, and by the country at large. Landslides management framework includes: information on prediction and warning, risk assessment or vulnerability analysis of landslide occurrence, and rehabilitation plans for each event. From natural hazards point of view landslide risk; the chance of landslide to happen that, will have an impact on human objectives or properties. It is measured in terms of consequence and probability. Recent advances in IT, RS and GPS have resulted in the creation of powerful tools, which empower to deal spatially with landslides disasters. These tools have used for dividing the above elements in to more specified objects for detailed study in sequential management scheme.

5.1 Landslides Risk Management Scheme

The value of a landslide risk assessment has always been and remains primarily dependent on the extent that the hazards are recognized and understood, Powell (2000).
Introduction of risk management scheme as the major strength of the landslide management system can be understood as answering the following questions:

- What might happen? (Recognition)
- How likely is it? (Probability)
- What damage or injury might result? (Consequence)
- How important is it? (Assessment)
- What can be done about it? (Recovery)

The previous questions can be answered through the following scheme components: zonation, assessment, and monitoring.

5.1.1 Zonation

Landslide Hazard Zonation (LHZ) refers to "the division of a land surface into homogeneous areas or domains and their ranking according to degrees of actual or potential hazard caused by mass movement" (Varnes, 1984).

The first task to identify various terrain factors which rule the stability of slope. Under the present study an attempt has been made to prepare a landslide hazard zonation map based on the combination of data acquired from various geological, geo-morphological and land use/cover thematic maps, which includes Tectonic Setting, Geological Setting, Slope Material(Weather Ability and Homogeneous), Discontinuity (Faults ,Joints, Number of Major Joint Sets and Spacing), Slope Dimensions (Slope, Aspect, Aperture , Persistence, and Height), Hydrologic Conditions (Rainfall and Water Content, Previous Instability, Land Use , Land Cover, and Drainage Pattern. Most of the previous parameters can be extracted from remote sensing data with field check. These parameters can be converted to digital format in GIS environment. Using special algorithm landslides hazard zonation map will be produced.

Remote sensing data and GIS techniques have been used to create thematic maps and overlapping them to produce final hazard map that leading to instability in the region by classifying the region to three categories: low, medium, and high risk using the integration of GIS with remotely sensed data at Pos Slim- Cameron Highlands region, Peninsular Malaysia (Figure 7).

5.1.2 Assessment

To judge or decide the potential, value, type or significance of a citrine slope stability. Assessment depends on internal slope factors while zonation done through the outer parameters. That's why the assessment still depends more on field work in compare with zonation which can be done through remote sensing data. Slope Assessment System (SAS) was developed to evaluate the risk of cut slopes that used for East-West highway alignments in Peninsular Malaysia. This system based on risk hazard value (G-Rating) and potential instability (PI).

G-Rating used 13 geological parameters that proposed by experts engineers: geology, weather ability, joints, aperture, persistence, orientation, spacing, number of major joint sets, faults, hydrologic conditions, rainfall, slope height, and previous instability slopes. The geometrical characteristics and discontinuity of the slope mass are shown and analyzed using Schmidt net, to PI carried out using a technique which proposed by Markland (1972).

According to SAS a 70 cut slope along the second stage of east-west highway have been assessed to three categories: no risk, low risk, medium risk and high risk. The comparison between the SAS out put and field check shows a high accuracy. Later on SAS converted to Expert System which can assess, categorize and give recommendations to any cut slope.

5.1.3 Monitoring

According to pervious phases, slopes with a high potential to slide will be put under surveillance. There are two main techniques for landslides monitoring. First, is in site using geotechnical or surviving tools, while the second implemented using remote sensing techniques.

Synthetic Aperture Radar (SAR) data with differential informatory will be choose for monitoring Pos Slim- Cameron Highlands region, Peninsular Malaysia (30X30 km^2) according to Table (1), For high risk slope category one of geotechnical techniques will be used according to slope morphology and significance.

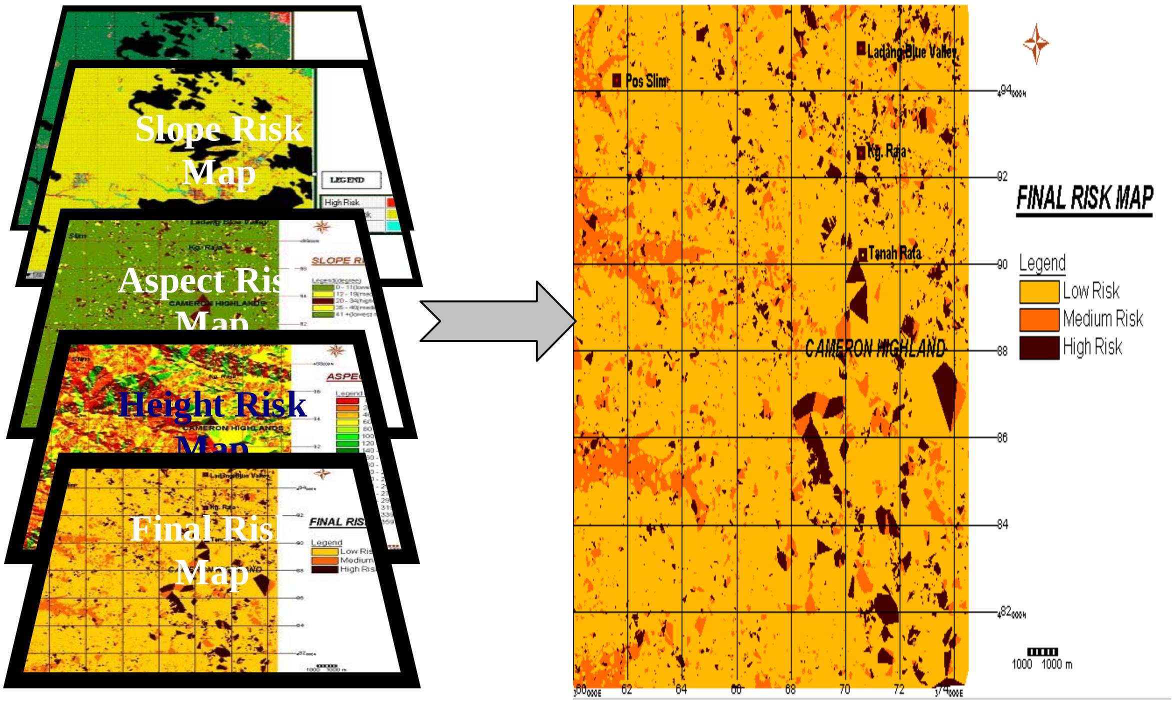

Figure 7: GIS data base and final risk map in Pos-Slim Cameron Highlands, Malaysia (Syed Omar at el 2004)

Location	**In Site**		**Remote**	
Type	Geotechnical	Surveying	Optical	Radar
Techniques	Strain meter Tensio meter Tilt meter Geophone	EDM[1] GPS[2] Triangulation Geometric Leveling	Arial Photography Satellite Images[3] Lidar Imaging	HSMR[4] SAR[5]
Accuracy	Millimeters	Millimeters	Centimeter-Millimeters	Centimeter-Millimeters
Installation Cost	High	High	Medium-Low	Low
Operating Cost	High	Medium	Low	Low
Durability	Low	Medium	High	High
Maintenance Requirements	High	Medium	Low	Low

Table 1: Landslides Monitoring Techniques

[1] Electronic Distance Measurement
[2] Global Position System
[3] High Spatial Resolution
[4] High wall Stability Monitoring Radar
[5] Synthetic Aperture Radar

6. CONCLUSION

Spatial information technology is useful in dealing with natural hazards to support increased coordination among multiple programs of risk management by examining the application of these technologies to the task of identifying, analyzing, assessing, treating and monitoring. The spatial technology can be used for provision of rapid and continuous data for flood forecasting and environmental monitoring, for landslide hazard zoning and assessment; and forest fire fighting and monitoring.

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