BIG DATA ANALYTICS (BDA) IN FORECASTING FOREST FIRE IN PERMANENT RESERVED FOREST (PRF), PENINSULAR MALAYSIA

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Abstract

Weather variations such as heat waves are among the causes of forest fire incidents in Peninsular Malaysia. The phenomenon has left adverse effects on forest ecology such as habitat loss and loss of biodiversity. Early and preventive information is vital to avoid such incident. Based on this situation, Forestry Department Peninsular Malaysia (FDPM) in collaboration with Ministry of Energy and Natural Resources (KeTSA) has developed a forest fire incident forecasting system in permanent reserved forest (PRF) in Peninsular Malaysia using Big Data Analytics (BDA). The system will enable FDPM to 1) forecast the areas of potential forest fires as early as seven days; 2) locate the relevant agencies to deal with forest fires close to the site of the fire incident that can be identified; 3) locate the nearest water resources; and 4) estimate the cost of the firefighting operations. Based on the implementation of BDA system, it is recommended for FDPM to expand further the application on other disasters such as landslides in steep areas, water head incidents in the eco-forest park areas and debris flow that usually occurred in PRF areas.

Key words: BDA, Forest Fire.

1.0 INTRODUCTION

Forest in Peninsular Malaysia is a valuable asset that brings a wide range of benefits and services such as timber and fuel, tourism, protection of watersheds and carbon storage (*Kamaruzaman & Dahlan, 2008*). However, forest fire incidents are becoming a major concern as they pose threats to the environment, economy and human safety. Based on Vadrevu*et.al* (2010) and also Sivrikaya *et.al.,* (2014), an understanding of forest fire risks is crucial.

Most of the forest fire incidents in Peninsular Malaysia are originated from sources outside of the forest, such as by humans (farmers and plantation holders) through open burning. Improper open burning techniques with strong wind causes the fire to spread to nearby forest areas. Based on historical records, forest fire phenomenon in Peninsular Malaysia has proven natural; undisturbed forest very seldom gets burned and even if they are affected it is usually not widespread (*Kamaruzaman & Dahlan, 2008*). There have been cases where the fire originated from inside the forest caused from the campsite fires made by campers and hunters that were not properly extinguished. In wetland forests, particularly the peat swamp forests, water can get dried up if subjected to prolong dry conditions; El-Nino Southern Oscillation (ENSO) phenomenon, hence rendering them very prone to fire. When such areas particularly the peat swamp forests get burn, the fire spreads underground and can continue burning for long period of time. The burning also tends to release a higher concentration of smoke and pollutants to the atmosphere compared to surface fires. As many as 12,000 hectares of 254,000 hectares of peat forest in Peninsular Malaysia have been exposed to forest fires that have resulted in significant losses including the loss of biodiversity. Continued incidents will also have a major impact on the air quality locally and could worsen throughout the country as a whole.

2.0 FOREST FIRE INCIDENT IN PENINSULAR MALAYSIA

Forestry Department Peninsular Malaysia (FDPM) as a government agency that responsible for the management, planning, protection and development of the Permanent Reserved Forests (PRF) in accordance with the National Forestry Policy (NFP) 1992 and the National Forestry Act (NFA) 1984, is aware about the forest fire incident and continuously monitoring forest fire incident in Permanent Forest Reserves (PRF). Preventive and control measures against forest fire in the PFR have been taken, including with the collaboration of the Malaysian Space Agency (MySA) and the Malaysian Meteorological Department (MET Malaysia) to obtain updates on hot spot and fire risk areas. FDPM is also working with the Department of Minerals and Geoscience (JMG) to build tube wells and check dams in areas with risks of catching forest fire. To date, 85 tubes have been built in the peninsular plus forest fire observation towers were also built in areas with potential to catch forest fire and fire-fighting equipment ready for use in forest fire fighting operations. Generally, fire can be detected from the satellite that will be marked as small fire icon. Satellite technology will detect if there are any fire hotspot (fire hazard area) is occurred into a certain in forest reserves area. This capability to detect fire makes forest fire prediction as an essential function in preventing or minimising the impact of the forest fires (Sitanggang*et.al.,* 2013).The impacts of forest fire can be minimised by having an early detection system. The essence of a good early detection system is quick detection of forest fire and the response of forest fire suppression team to put out the forest fire. The application of remote sensing and geographic information technology, extensive weather observation system and big data analysis can be utilized in the development of early detection system for forest fire. This system will further enhance and complement the capability of FDPM to suppress forest fire more effectively by using the state-of-art technology.

When a forest fire prediction can be implemented, resources of the agencies can be planned in mitigating the process of suppressing and curbing the fire from getting into an uncontrollable size. Many factors such as meteorological condition, land use, settlements, types of forests and others can be used for the analysis of forest fires prediction (Pourtaghi *et.al.,* 2016). Meanwhile, the water source can be planned for arrangements before going to a site for a forest fire operation. Finally, the cost of the fire operation can be predicted depending on the area of the location.

3.0 WHAT IS BIG DATA ANALYTICS

Big Data Analytics (BDA) is a tool to examine large amounts of data to uncover hidden patterns, correlations and other insights. With today's technology, everything is possible to analyse data and get answers from it, almost immediately. In general, BDA helps organizations harness their data and use it to identify new opportunities which will leads to smarter organization moves with more efficient operations such as :

a. Reducing cost
   Big data technologies like cloud-based analytics can significantly reduce costs when it comes to storing large amounts of data (for example, a data lake). Plus, big data analytics helps organizations find more efficient ways of doing business;

b. Making faster, better decisions
   The speed of in-memory analytics – combined with the ability to analyse new sources of data, such as streaming data from IoT – helps businesses analyse information immediately and make fast, informed decisions; and

c. Developing and marketing new products and services
   Being able to gauge customer needs and customer satisfaction through analytics empowers businesses to give customers what they want, when they want it. With big data analytics, more companies have an opportunity to develop innovative new products to meet customers' changing need

In BDA, there are three (3) types of data analytics:

a) **Descriptive Analytics** are the conventional forms of Business Intelligence and data analysis. It seeks to provide a description or summary view of facts and figures in an understandable format. It uses two primary techniques, namely data aggregation and data mining to report past events. As this form of analytics doesn't usually probe beyond surface analysis, the validity of results is more easily implemented. Some common methods employed in Descriptive Analytics are observations, case studies, and surveys.

b) **Predictive Analytics** are used to make predictions about unknown future events. Techniques from data mining, tatistics, modelling, machine learning and artificial intelligence are used to analyse historical and current data to forecast future events. Predictive analytical models capture relationships among several factors for risk assessment with a common set of conditions for assigning a score or weighting. By applying predictive analytics, businesses can effectively interpret big data for their benefit.

c) **Prescriptive Analytics** provides organisations with recommendations around optimal actions to achieve business objectives. Prescriptive analytics also referring to the factors that deliver information on possible outcomes or scenarios and suggests a course of action

or strategy. In other words, prescriptive analytics anticipates what, when and why it happened and thus suggests options to diminish further threats. Furthermore, prescriptive analytics can improve prediction accuracy after adjusting with the new data that has been inserted.

In Malaysia, Big Data Analytics starts in 2015 with Public Sector Big Data Analytics Pioneer Analytics Projects. This project developed 4 business cases involving 4 agencies namely MAMPU for Sentiment Analysis, Ministry of Domestic Trade and Consumer Affairs for Price Monitoring, Ministry of Health Malaysia for the Hand, Foot and Mouth Disease (HFMD) and Royal Malaysian Police for Crime Prevention. The Public Sector Big Data Analytics Pilot Project has also provided facilities (info/infrastructure) for the implementation of the Public Sector Big Data Analytics by the Public Sector agencies that encompasses Framework, Governance, Methodology, Platform, Circular, Competency Development and Advisory Services of Big Data.

Parallel to the Big Data phenomenon and government intention to drive the ICT service, the Malaysian government announced the implementation of the Public Sector Big Data Analytics Pilot Project. In the Malaysian MSC Implementation Ceremony Meeting No. 25 on 14 November 2013, the honourable Prime Minister announced that the Ministry of Communications and Multimedia in collaboration with MAMPU and Malaysia Digital Economy Corporation (MDeC) will lead the implementation of Malaysia's Big Data Analytics (BDA). The meeting also reached an agreement that the Ministry of Communications and Multimedia will develop the Malaysia's Big Data Framework in collaboration with MAMPU and MDec; MAMPU and MDec to collaborate in the implementation of the Public Sector Big Data Analytics Pilot Project; and MDec to lead in the inception of Private Sector BDA. Focusing on the mandate received, various Big Data initiatives are implemented whether through project implementation or by Proof of Concept (POC) to enhance the government capability in making decisions based on facts and data, development of local talents and at the same time, responding to the critical demand/need of the national transformation agenda. Overall, BDA provides solution to support the management and analysis of multidimensionality, volume, complexity and variety of earth-related datasets and support scientific analysis process through parallel solutions (Kaplan and Mikes, 2012). BDA deals with collection of digital data, which come in diverse forms, in order to reduce uncertainty in decision making (Ali *et. al*., 2016).

For this project that implementing **Prescriptive Analytics BDA**, Forestry Department Peninsular Malaysia (FDPM) is collaborating with Ministry of Energy and Natural Resources (KeTSA) to develop a Forest Fire Incident Forecasting System in Permanent Reserves Forest (PRF) in Peninsular Malaysia using Big Data Analytics (BDA). KeTSA is the ministry that initiates and sponsors this BDA project. It also coordinates the flow and direction of the BDA development in terms of monitoring both the financial and the project progress itself. KeTSA is responsible to lead in the areas of sustainable management of natural resources and conservation of the environment towards achieving the national vision. There are 11 departments under KeTSA including FDPM. KeTSA is implementing Big Data Analytics to increase its service capabilities and serve the needs of all agencies under its purview. Forest fire incidents information is one of the key sources of an informed decision making in planning for sustainability development. In line with the need to address these issues and to implement more effective forest management strategies.

4.0 HOW DOES BIG DATA ANALYTICS (BDA) HELPS IN FOREST FIRE FORECASTING?

Forest Fire Forecasting System in Permanent Reserves Forest (PRF) in Peninsular Malaysia using Big Data Analytics (BDA) is initiated by Ministry of Energy and Natural Resources (KeTSA) to assist FDPM on analysing and forecasting forest fire incidents that occur in PRF of Peninsular Malaysia. Based on the current practice, a forest fire incident can only be known

when someone makes a report after an observation. By the time related agencies arrived at the scene, the forest fire may have become huge and sometimes catastrophic, which will cost a lot of resources in fighting the forest fire. To reduce the required resources that need to be borne by the government and other parties, early preventive measures should be adopted so that actions can be taken in preventing the forest fire to happen or spread to a larger area. The impacts of forest fire can be minimised by having an early detection system. The essence of a good early detection system is quick detection of forest fire and the response of forest fire suppression team to put out the forest fire. This system will further enhance and complement the capability of FDPM to suppress early stage of forest fire more effectively. When a forest fire prediction can be implemented, resources of the related agencies can be planned in mitigating the process of suppressing and curbing the fire from getting into an uncontrollable size. At the same time, the cost of the forest fire operation can be predicted depending on the area of the effected location. Finally, the water source can be planned for arrangements before going to a site for a forest fire operation.

Forest Fire Incident Forecasting System in Permanent Reserves Forest (PRF) in Peninsular Malaysia using Big Data Analytics (BDA) has produced four (4) focus subject that will help FDPM combating the forest fire incidents on early stage.

4.1 Predicted the forest fire hazard potential area in PRF

The forest fire hazard potential area in PRF will be plotted into a map. This is based on Fire Danger Rating System (FDRS) that provides information to support fire management. FDRS will predicted fire behaviour that will facilitated FDPM to make decisions on fire mitigation and smoke haze pollution. Colour coding were used as shown in **Table 1.**

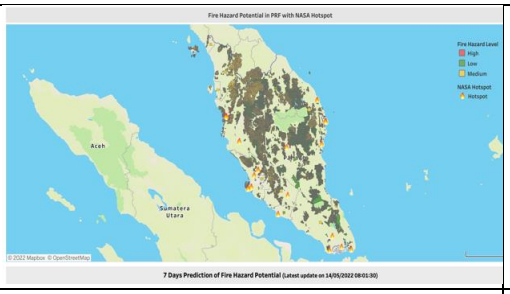
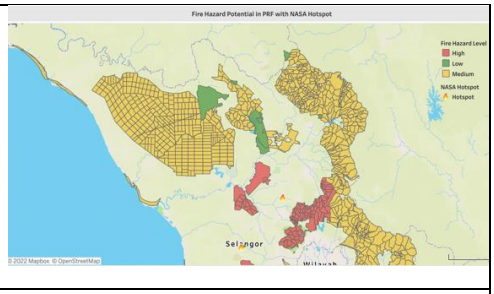
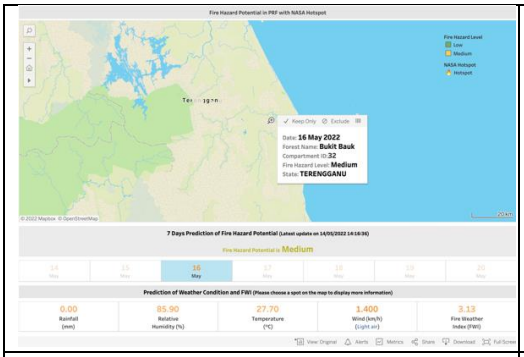
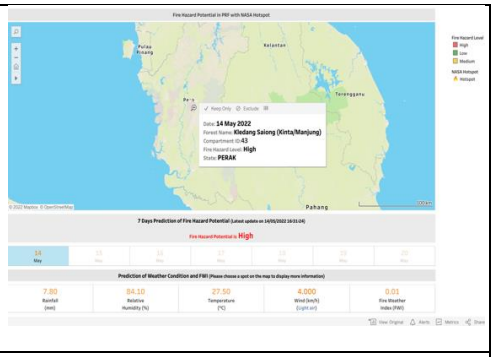
Table 1 – Fire Danger Rating System (FDRS) Colour Coded

FDRS Colour Coded	Interpretation
Blue	Low Probability of fire occurring/ top soil are wet / typical wet season / amount of fuel generally low and not combustible
Green	Moderate probability of fire occurring / top soil are moist / Normal mid dry season conditions / amount of fuel medium for combustion
Yellow	Higher probability of fire occurring / top soil becoming dry / Mid dry season, 5-15 days to reach threshold, all open burning should be restricted / medium to heavy amount of fuel for combustion
Red	Very high probability of fire occurring / top soil very dry / less 5 days to reach threshold, complete burning restriction / heavy amount of fuel for combustion

The current forest fire hazard potential in PRF areas will show the real-time map that is considered as happening now (present day) whilst prediction Map has shown present day of hotspot in PRF areas in Peninsular Malaysia can be calculated up to 7 days. The prediction forest fire hazard potential in PRF areas consists of required data that are essential for further processing that includes previous forest fire hazard potential in PRF areas, forest fires history and previous weather condition. Fire Weather Index

(FWI) works as one of the input alongside with other data such as meteorological data, settlements, land use and roads. If an area has a red FWI indicator, it is likely that the probability of the hotspot occurrence is high. By having this indicator, this will assist in increasing the accuracy of forest fire hazard potential prediction together with other data. **Figure 1** shown the predicted forest fire forest fire hazard potential area in PRF on map.

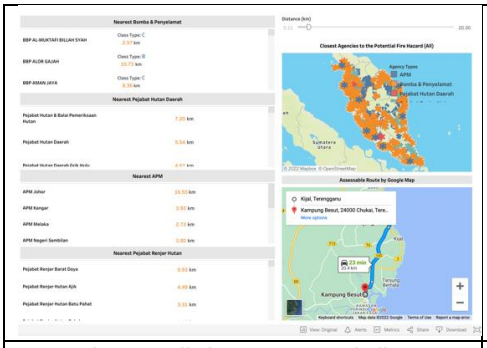
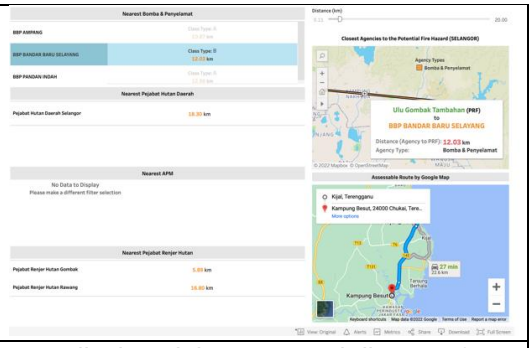
Figure 1 – Maps of forest fire hazard potential in PRF areas using the FDRS coded

	
Map has shown present day of forest fire hazard potential in PRF areas in Peninsular Malaysia	Map has shown present day of forest fire hazard potential in PRF focused in State of Selangor
	
Map has shown prediction of forest fire hazard potential in Bakit Bauk PRF, Terengganu with data of FWI calculated by the system.	Map has shown present day of forest fire hazard potential in Kledang Saiong PRF, Perak with data of FWI calculated by the system.

4.2 Identification nearby firefighting agency (location and distance)

BDA can also calculated and identified the route and distance from the current forest fire hazard potential in PRF area to the nearby firefighting agency facilities such as JBPM, APM, Forest District Office, Forest Ranger's office and Forest Fire Observation Tower. The route and distance will be displayed in the mouse-over box on a map. At the right-side panel, a histogram of the nearest agencies to the current forest fire hazard potential in PRF area will be displayed. The input data for this tasks are the location of JBPM, APM, Forest District Office, Forest Ranger's office and Forest Fire Observation Tower. At the processing stage, the acquired data will be tabulated on the map so that distance and routing calculation is performed using the map's application. **Figure 2** shown the route and distance from the nearby firefighting agency to the current forest fire hazard potential in PRF areas.

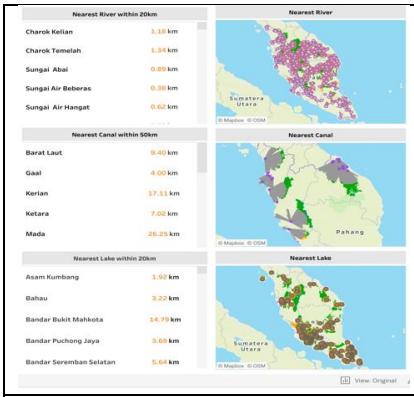
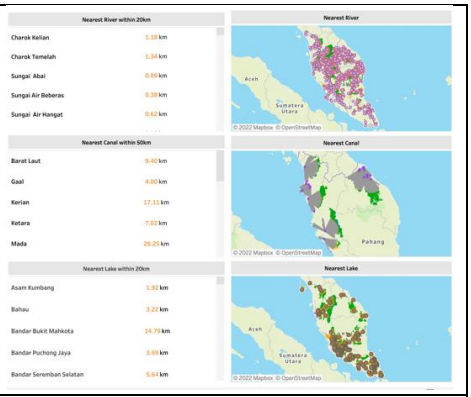
Figure 2 - The route and distance from the nearby firefighting agency to the current forest fire hazard potential in PRF area

	
Map shown all the route and distance nearby firefighting agencies.	Map displayed the route and distance from selected forest fire hazard potential in PRF and firefighting agency. .

4.3 Identification of the water location sources and other facilities for the Forest Fire Operation

The system was set to locate the nearest water sources such as river, canal and lake nearby and other facilities such as tube well, check dam available and also Watch Tower that was built to the nearest predicted hotspot location. This will securing enough supply of water for extinguishing forest fire operation mainly in extremely difficult terrain, represents a difficult issue in tactics of fires extinguishing. **Figure 3** shown some of the water sources and other facilities that the system managed to locate.

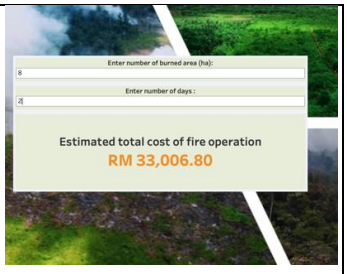
Figure 3 : Water source and other facilities identified by BDA

	
Map shown the location of the nearest Tube well, Dam within 20 kilometres and nearest Observation Tower within 50 kilometres.	Map shown the location of the nearest river and lake within 20 kilometres and nearest canal within 50 kilometres.

4.4 Calculation of the estimation cost of firefighting operation

BDA can do the calculation for estimation of the cost of firefighting operation. The expected output would be the overall cost that will be incurred for a forest fires operation. At this stage, a correlation between area sizes and the duration of the firefighting operation cost will be used. The value of the expected cost will be displayed at the side panel of the screen on the selected hotspot as can be seen in **Figure 4.**

Figure 4 - Predicted Cost for Firefighting Operation

		
Items that included to the system to do calculation for costing.	Display before inserting the affected area and estimation period of the operation.	Display after inserting the affected areas and estimation period of the operation.

5.0 ENHANCING FOREST FIRE INCIDENT FORECASTING – THE WAY FORWARD

Developing a forecasting system on forest fire incident using Big Data Analytics with a collaboration with Ministry of Energy and Natural Resources (KeTSA) is a breakthrough and first of its kind. Top management of FDPM has instructed that this system to be used in monitor forest fire incidents in all permanent forest reserves in Peninsular Malaysia through involvement of the State Forestry Department. The system has been fully handed over to FDPM by KeTSA on 15 March 2022 and to be maintained and monitored by the Information Management Division, FDPM and coordinated by the Forest Plantation and Forest Protection Division, FDPM. This system is also used in the FDPM War Room to continuously monitor forest fire incidents in the Permanent Forest Reserve in Peninsular Malaysia.

Hence, to ensure the continuation of using Big Data Analytics in monitoring forest fire incident, FDPM has to set an approach the way forward in BDA as below: -

5.1 Continuous training for Officer-In-Charge of forest fire

The importance of BDA is not about the data availability but how the organization used the collected data and turns it into actionable insights. The insights will help in better decision making, cost saving, time reducing, better market condition understanding and gauge customer need. Therefore, a series of workshop and training is needed to guarantee the BDA comprehension and acceptance. Thus, continuously training to the officer-in-charged of forest fire monitoring and reporting will help them understand better on the results from the system so that they could respond quickly. Apart from that, the reports generated through the BDA system can help FDPM take appropriate action immediately.

5.2 Enhancement of the BDA

The BDA is just a beginning in the use of data-related technologies. Various improvement can be implemented to provide more efficient in decision making and more complete reporting. Installation of control cameras to provide early detection of forest fire early detection system through thermal analysis is the most efficient solution. This type of system allows early detection, location and monitoring of forest fires. The system to be implemented for the prevention and detection of forest fires is generally made up of a control center and one or more surveillance posts. The temperature in each of these surveillance posts is constantly monitored. Using advanced software and algorithms, fires are quickly and automatically identified and located as soon as they start. It also can integrate with BDA system.

Artificial Intelligence (AI) is more competitive and efficient to reap the benefits of big data. Integrating new technologies like cloud technology and big data will allow organizations to gather data in the cloud, analyse it in real-time and use this information to obtain insights to improve product and service quality and efficiency. With the convergence of big data and cloud computing, there is a world of possibility ahead where organizations can take their products or services to an entirely new level.

5.3 Expansion of BDA for other natural disasters

Various natural disaster happens in the PRF such as accumulation of driftwood and debris, landslides, and water surges due to heavy rain and floods has alerted FDPM. Therefore, the use of BDA system in monitoring high slope data, rainfall data distribution, forest cover that will involve various agencies in assisting FDPM to overcome the matter. Therefore, the use of BDA should be a catalyst to overcome or to reduce the impacts of these disasters.

6.0 CONCLUSIONS

The development of a Forest Fire Incident Forecasting System in Permanent Forest Reserves in Peninsular Malaysia using Big Data Analytics (BDA) has proven and managed to empower an effective monitoring system on forest fire. This will reduce the spread of forest fires and minimize the cost of forest fire fighting operations. Apart from that, BDA system will support FDPM to preserve forest biodiversity and many more. Even though BDA approach by KeTSA and FDPM is still at the initial stage; the implementation is vital to change mind set of the staff and related agencies towards the idea of BDA. There are several benefit that can be achieved by using the forecasting system with BDA such as early preparation by the FDPM monitoring team to the field even before the forest fire occurred besides identified relevant agencies nearby the predicted location for early preparation. In addition, FDPM monitors the occurrence of forest fires in formulate policies, work plans and mitigation measures in forest fire management to reduce forest loss and destruction and its consequences to the forest and its ecosystem. FDPM should explore more in BDAs technologies to make use of all the data by defining the Big Data approach. This will enhance FDPM in harvesting data in real time and to effectively give the new dimension in harnessing the data and to meet the expectation in the world of technologies.

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