# TOWARDS AN INTEGRATED FIRE MANAGEMENT FRAMEWORK USING SPACE-BASED APPLICATION IN ASIA-PACIFIC REGION

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## Abstract

The integrated fire management framework using space-based application has been developed to reduce the consequences of fire disaster, particularly in developing countries, least developed countries (LDCs), small island developing states (SIDs) and land-locked developing countries (LLDCs) in Asia and the Pacific. Since 1982/1983 and 1997/1998, the two recorded forest fires in the world created much suffering in Asia and the Pacific region, while the resulting transboundary atmospheric pollutant and increasing $CO_2$ emissions contribute to global warming. Fire disasters continue to frequently occur. Therefore the framework to strengthen the effective production and utilization of space information products and services for integrated fire management is much needed. The framework in the study consists of: (1) intensifying risk identification; (2) enhancing risk processing; (3) strengthening risk information transfer, evaluation, and reduction; and (4) promoting regional and international cooperation. The complex framework is derived from lessons learned from grassland and forest fires that severely hit countries in Asia and the Pacific, namely The Russian Federation, Australia, Indonesia, Thailand, China, Mongolia, and Nepal. All of which highlight the need for improved usage of space information products and services.

## 1. Introduction

One of the climatological disasters which occurs periodically is fire disasters due to natural and anthropogenic activities. Natural activities that can cause such fire disasters include drought phenomenon, lightning, volcanic eruptions, pyroclastic clouds, underground coal fires, sparks from rockfalls, and spontaneous combustion from coal material, while the major contributing factors to wildfires in Asia and the Pacific comes from anthropogenic activities such as discarded cigarettes, sparks from equipment, and conversion of forest to other land-use (deforestation) (FAO, 2006).

The potential of fire spreads to secondary fuel sources such as houses, roads, electric power lines, bridges, etc. In addition to meteorological conditions and fuel combustion, affects the speed and ability of fire to spread to an extensive area. Such disasters cause great damage, both to property and human life, and they negatively impact the ecosystems, decreasing species and biodiversity, and on environments by introducing smoke, particulate matter and increasing of $CO_2$ concentrations in the atmosphere which support global warming.

The International Disaster Database (EM-DAT, 2010) statistics show that economic losses caused by fire disaster, especially by forest fire and grassland fire in the world totaled US$ 19.6 billion for the period 1990-1999 and decreased slightly for period 2000-2008 to US$ 15.4 billion. The highly intensive wildfires period for 1990-1999 was due to climatology trigger of El-Niño phenomenon which made the weather unusually dry. These harse conditions were reported by international agencies, researchers and many countries including Asia and the Pacific countries in 1997/1998 (Enfield, 1998; IDNDR-UNESCAP, 1999; NOAA, 1999; WMO, 1999; Luh Made Chandra *et al*., 2006; Changnon, S.A. (editor), 2000; Wang *et al*., 2001). During the period 1990-1999, the impact on human lives is estimated at 820 casualties and 3.5 million people affected. The Asia and Pacific region is among the most fire disaster prone in the world, contributing to 59.1 percent of the total deaths, 93.8 percent of the total number of affected people and 61.7 percent of the total economic losses (EM-DAT, 2009). The losses from countries with low capacity building and infrastructure for forest fire, bush fire and grassland fire monitoring are reported below.

Table 1 presents the statistics of the 2009 fire disaster with economic losses caused by grassland and forest fires in Asia and the Pacific region, with the most severely hit countries, namely The Russian Federation, Australia, Indonesia, Thailand, China, Mongolia, Nepal, etc.

Table 1 illustrates the comparison of intensity of fire disaster effects in Asia and the Pacific region with the records of 19 countries. The record showed that 3 countries were severely affected by grassland fire and forest fire (more than 9 fire disasters); 6 countries were moderately affected by forest fire (more than 2 fire disasters); and 10 countries were less affected by grassland fire and forest fire (less than or equal to 1 fire disaster).

The countries with severe and moderate wildfire intensities will be elaborated in this study. The Republic of Kazakhstan and The Russian Federation represent countries from the North and Central Asia sub-region. China and Mongolia represent

**Table 1.** Fire disaster in countries in Asia and The Pacific (period 1990-2009).

| Region/ Country | No. of disaster | People Killed | People Affected | Damage (US$) millions |
|---|---|---|---|---|
| **North and Central Asia sub-region** | | | | |
| Russian Federation | 19 | 19 | 102,403 | 383.3 |
| Kazakhstan | 1 | | 8,000 | 62.9 |
| Iran (Islamic Republic of) | 1 | | 222 | 3.5 |
| Afghanistan | 1 | | | |
| **East Asia sub-region** | | | | |
| China | 3 | 52 | 300 | |
| Mongolia | 2 | 25 | 5,061 | 1,822.8 |
| **South Asia sub-region** | | | | |
| Nepal | 2 | 88 | 54,000 | 6.2 |
| India | 1 | | | |
| Bhutan | 1 | | | 2 |
| **Southeast Asia sub-region** | | | | |
| Indonesia | 9 | 300 | 3,034,478 | 9,329 |
| Thailand | 5 | | | 403 |
| Malaysia | 4 | | 3,000 | 302 |
| Korea (Republic of) | 3 | 2 | 5,150 | |
| Vietnam | 1 | | | |
| Philippines | 1 | | | |
| Japan | 1 | | 8,000 | |
| Brunei Darussalam | 1 | 6 | | |
| **Pacific sub-region** | | | | 2,033.7 |
| Australia | 16 | 213 | 65,970 | |
| Papua New Guinea | 1 | 2 | 300 | |

Source: EM-DAT, 2009.

countries from the East Asia sub-region. Nepal and India represent countries for the South Asia sub-region. Finally, Indonesia and Thailand represent countries from the Southeast Asia sub-region and Australia represents country from Pacific sub-region.

The objective of this study is to promote a framework of integrated fire management using space information products and services combined with field observation that consist of: (1) intensifying of the risk identification; (2) enhancing of the risk processing; (3) strengthening of the risk information transfer, evaluation, and reduction; and (4) promoting of the regional and international cooperation.

## 2. Risk Identification

Risk identification involves preparing satellite/ Radar data and observation historical data, including not only atmosphere and land data for present day analysis but also ocean data for future analysis, to establish the Fire Weather Index (FWI), and mapping for risk assessment in fire disaster prone areas. After these activities, we try to simulate FWI based on real time data, and future scenario data like IPCC data to establish early warning systems for the following part on risk processing.

### 2.1. Major Causes of Fire Disaster in Asia and the Pacific

#### 2.1.1. Anthropogenic Activities

The major causes of fire disasters in Asia and the Pacific is anthropogenic activities most notably in the forestry sector such as illegal logging and conversion of forest to another land-use such as infrastructure, transmigration, shifting cultivation, agriculture for increasing food supplies, and facilities as known Land Use, Land Use Change and Forestry (LULUCF) (IPCC, 2007). These activities are a result of an increasing population and a continued expanding of the plantation industry and estate crops including palm oil plantation, especially in Indonesia which will expand by six million hectares by 2020 in order to supply the global palm oil market (WWF, 2002).

The source of fire disasters from logging company and industry plantation activities is the use of fire for land clearing. The fire method is widely used as it is the cheapest, the fastest and the most effective land clearing method (Ketterings *et al*., 1999), even though this method is already banned in several countries (Indonesia, Mongolia, Russian Federation) due to the largest forest fire events during the period 1997-1998.

Based on EM-DAT data, Indonesia experienced the two largest fire disasters in the world due to anthropogenic activities of misuse and mismanagement of tropical rainforests, leading to deforestation and degradation plus added natural activities triggered by extreme climate during periods 1982-1983 and 1997-1998. Also from the EM-DAT data, the primary causing of fire disasters in Australia is due to extreme climate together with human-made reasons such as arson, and the careless disposable of cigarette butts (National Climate Center, 2009).

#### 2.1.2. Natural Activities

The main natural case of forest fire is extreme drought climate, defined by a high degree of dryness caused by high temperatures and lack of precipitation. If the extreme drought climate, high temperature and lack of precipitation continues for an extended period of time (3-6 months), the dry biomass organic and peat land become fuel for the fire due to friction from high wind speed (McMahon, 1983).

Extreme drought climate is highly variable among sub-regions in Asia and Pacific as a result of climate variability especially from ocean oscillation in the warm phase. They are the El-Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) phenomenon near in Pacific Ocean, the North Atlantic Oscillation (NAO) phenomenon near in Atlantic Ocean, and the Indian Oscillation Dipole (IOD) phenomenon near in Indian Ocean.

According to Wolter (1987), and Wolter and Timlin (1993), the Multivariate ENSO Index (MEI) integrates more information to indicate forest and grassland fires. It consists of six main observed variables, namely sea-level pressure (P), zonal (U) and meridional (V) components of the surface wind, sea surface temperature (S), surface air temperature (A), and total cloudiness fraction of the sky (C). Figure 1 shows the relationship of MEI with positive value related warm phase (El-Niño) and fires that occurred in Asia and the Pacific during the periods 1982-1983 and 1997-1998; Russian Federation and Kazakhstan during the periods 1986-1987 and 1997-1998; China and Mongolia in 1987 and 2000; Nepal and India during the periods 1985-1987 and 2000; Thailand during the period 1985-1986 and 1992-1993; and Australia in 1991, 2003 and 2006.

### 2.2. Season for Fires in Studied Countries

In the North and Central Asia sub-region, The Russian Federation and Kazakhstan have experienced severely intense forest fires. The potential burn area was approximately 6.3 million hectares in the period 1997-1998 and 11.8 million hectares

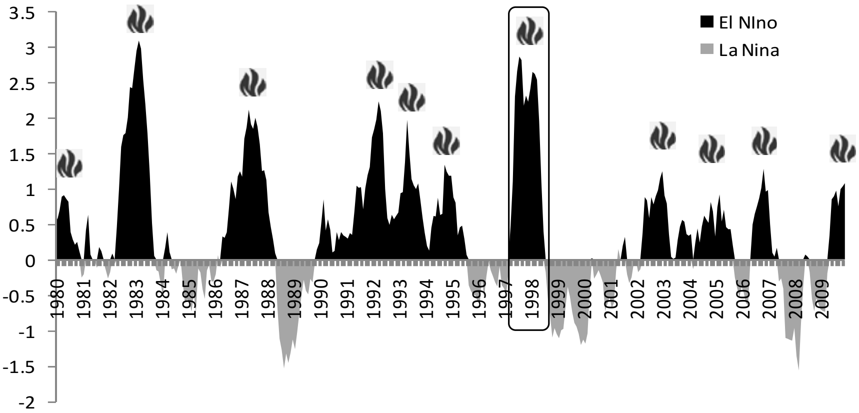



**Figure 1.** Multivariate ENSO Index (MEI) during 1980-2009 (NOAA, 2010) with fire occurred in Asia and the Pacific.

in the period 2000-2004. During the period between 1990 and 1999, The Russian Federation suffered more from fire events which resulted in the loss of 67 lives and affect 101,283 people with an economic loss of US$ 383.3 million (EM-DAT, 2009). The fire season in northern Kazakhstan starts in the middle of April and runs to the end of October, while the southern part is between February/ March and November. On the other hand, the fire season for western Russia (Siberia) rekindles annually from May-June; July through September for eastern Russia (Yakutia and Magadan); July for north-west Russia; and September till mid-October for the southern Russia (GFMC, 2001).

Nepal and India have experienced big forest fires in the South Asia sub-region. The estimated burnt forest fire areas of 400,000 hectares in 1995 and during the periods 1985-1987 and 2000 were approximately 2.99 million hectares and 3.70 million hectares respectively. Based on the Forest Resources Assessment (FRA 2005, FAO 2006), the forest fire that occurred in 2000 cost both countries combined economic losses of US$ 110.6 million. Also the fire disasters caused 300 fatalities, with around 20,000 people affected. The fires usually rekindle during the hot and dry season from March to May in Nepal. While India suffered from the fire out-burst during the dry conditions experienced from January to June (GFMC, 2002).

China and Mongolia are examples of the suffering countries from fires in the East Asia sub-region. The evaluation event of forest fire in 1987 was around 1.33 million hectares and 23.1 million hectares during the period of 1996-1997. Damage from Mongolia fires included five deaths, the destruction of 56 dwellings, 2,500 livestock, 30 winter animal shelters, 70 tons of hay and 10 wells (UNDP, 1996). The fires occur periodically during the period from March−June and September−November in northeast China and January−June and October−December in southwest China. While the fires in northeast Mongolia rekindles annually from April−July (80%) and September−October (5-8%) (GFMC, 2002).

The forest fires in the South East Asia and Pacific sub-region are from the two larger forests in Indonesia during the periods 1982-1983 (3.5 million ha) and 1997-1998 (9.7 million ha). The other countries in this sub-region were Thailand and Australia which experienced forest fires during the period of 1985-1986 (7.3 million ha) and 1998 (1.1 million ha), and the worst bushfire in 2009 (0.45 million ha). The fires occur periodically mostly during the months from August to October in Kalimantan and Sumatera of Indonesia, which is covered with peatland. The other countries that are the risk annually during the months from February−March is the northern, northeast, and southern part of Thailand; while Australia is at risk from December−February in the south and September−November in the east (GFMC, 2002).

The largest fires (1997-1998) in Indonesia caused 243 fatalities, affected 34,070 people, and resulted in economic losses of US$ 9,300 million (EM-DAT, 2009). While, the worst bushfire in Australia known as "Black Saturday Bushfire" caused 180 fatalities, affected 9,954 people, and caused economic losses of US$ 1,300 million (EM-DAT, 2009). The other consequences from the fire include environmental damage, losses of biodiversity, increasing $CO_2$ emission and the health affected by air pollution.

Figure 2 highlights the resumption of the fire season in Asia and Pacific countries which occurred frequently (70%) in post-monsoon in tropical area or autumn season for north hemisphere and spring season for south hemisphere. This condition is caused by the accumulation of drought extreme climate starting in pre-monsoon which is the minimum MEI, while the maximum MEI is peak of fire season (Figure 1). After that, the fire happens gradually (40%) in pre-monsoon in tropical area or spring season for north hemisphere and autumn season for south hemisphere due to accumulation of dry winter and post monsoon. The percentage of fire occurrence is more than 100% due to the double peak season in some countries with large land masses The Russia Federation, Indonesia, China, Mongolia and India. Totally fire events usually lag about 2-3 months or

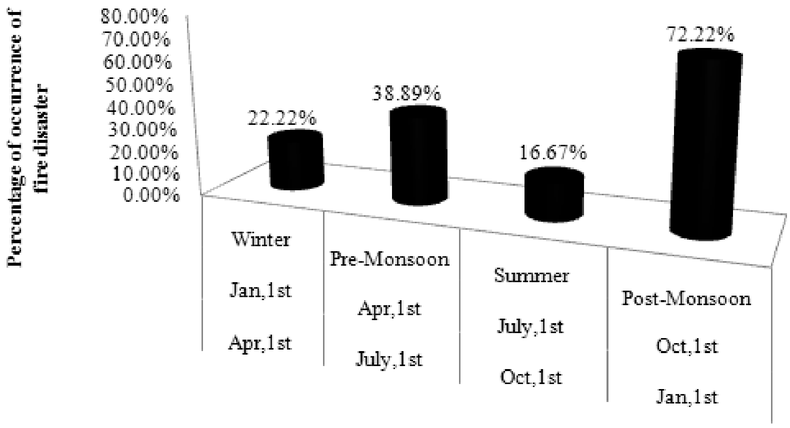



**Figure 2.** Fire season in Asia and the Pacific countries based on GFMC (2001,2002).
Note: Fire occurrence is more than 100% referred to the events of fire occurrence.

half a year after the MEI is measured at the minimum value until the maximum value in warm phase (El-Niño).

### 2.3. Estimation of $CO_2$ contribution from fire disasters

Based on IPCC Report (2007), the forest fire from LULUCF contributed significant $CO_2$ emissions to the atmosphere, especially from Asia Pacific region due to high risk forest fire. Their emissions from LULUCF contributed a large portion of total emissions based on the National Communication report of each country. This is estimated to be up to 58% from an Indonesia case study (MoE, 2009).

To estimate $CO_2$ emissions from forest fire, the empirical equation of fire is basically computed by Levine equation (1999) with the correction factor referred to IPCC Guide (2007). The equations are:

$$M = AB \times B \times E \quad \cdots\cdots (1)$$

$$CO_2\_E = M \times C \times CE \quad \cdots\cdots (2)$$

where M is the total mass of vegetation or peat consumed by burning (in tons), AB is area burned of vegetation (in ha), B is the biomass carbon stock (in tons/ ha), E is the burning efficiency (unitless), $CO_2$_E is the $CO_2$ emission (in tons carbon), C is the carbon content (unitless) and CE is the combustion efficiency (unitless). The biomass carbon stock of forest, and grassland/ bush is referred to Hendri (2011) in Table 2. For primary data, the large burn area is referred to the International Forest Fire News (IFFN) each country provided by the Global Fire Monitoring Center (GFMC).

**Table 2.** Value of B, E, C, and CE

| Type of Area | B* | E** | C** | CE** |
|---|---|---|---|---|
| Rain Forest | 430 | 0.2 | 0.45 | 0.90 |
| Grassland/ bush | 100 | 0.2 | 0.45 | 0.90 |
| Peat area | 330 | 0.5 | 0.50 | 0.77 |

Source: * Hendri (2011), **Levine (2009).

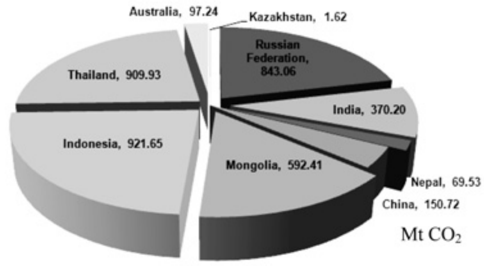
The total estimation of $CO_2$ emissions from representative countries in Asia and the Pacific can be classified into three periods, i.e.: 1980-1989, 1990-1999 and 2000-2009. The $CO_2$ emissions during the period 1980-1989 were dominant by the Southeast Asia sub-region, especially from Indonesia and Thailand estimated equivalent to 1,831.58 Mt $CO_2$. Following that, the emission inventoried is about 843.06 Mt $CO_2$ from The Russian Federation in the North Asia sub-region and 592.41 Mt $CO_2$ in Mongolia in the East Asia sub-region (Figure 3a).

The country which contributed the most $CO_2$ emissions during the period 1990-1999 changed to Mongolia in the East Asia sub-region accounted about of 2,836.73 Mt $CO_2$ equivalent. Indonesia contributed the second most in the Southeast Asia sub-region with a determined equivalent to be 2,578.80 Mt $CO_2$ and The Russian Federation in the North Asia sub-region lastly contributed 1,189.75 Mt $CO_2$ (Figure 3b).

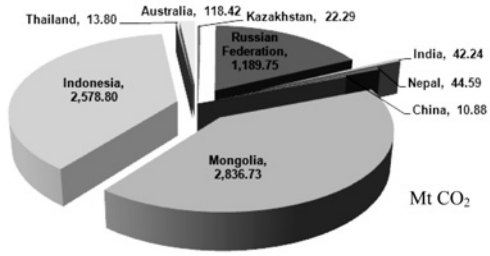
For the period 2000-2009, the biggest contributor changed to The Russian Federation in the North Asia sub-region with an estimated equivalent of 1,290.27 Mt $CO_2$. This is followed in rank by Indonesia in the Southeast Asia sub-region that accounted about of 938.51 Mt $CO_2$ and 631.03 Mt $CO_2$ in India (Figure 3c).

Total amount $CO_2$ emissions from fire disasters from the representative Asia region (Nepal, India, China, Mongolia, Indonesia, and Thailand) during the period 1980-1989 was caused by strong El-Niño occurrence, and for the period 1982-1983 contributed 4.9% to total $CO_2$ emissions of the world (WRI, 2007) and 22.4% to total $CO_2$ emissions of Asia region (excluding Middle East). The calculation of $CO_2$ emissions increased in the following period, an estimated two-three times larger especially during the period 1997-1998 due to the highest index oscillation of MEI. For the last decade, the fire area is slightly reduced compared to the two decades before due to an El-Niño index which was not as strong.

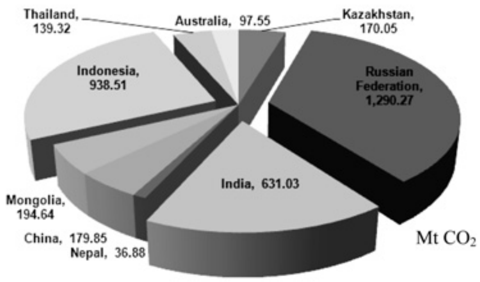
Fire disasters not only produce $CO_2$ emissions, but also smoke, particulate matter and cause an increase in temperature in both atmosphere and ocean temperature. Smoke and particulate matter became a transboundary issue when fire happened in Indonesia during the period 1997-1998. The other by-products, the accumulation of the $CO_2$ emissions to the atmosphere which relates to increasing temperature in Asia and the Pacific regions as shown in the graph of anomaly temperatures 2 meter above level sea or SST (Brohan et al., 2006). It estimated that up to 1 degree Celsius above the peak which occurred during the period 1998-1999, after the high of El-Niño in 1997/ 1998 (Figure 4).




(a) $CO_2$ emission period of 1980-1989.




(b) $CO_2$ emission period of 1990-1999.




(b) $CO_2$ emission period of 2000-2009.

**Figure 3.** $CO_2$ emission of three decade last in Asia and the Pacific.

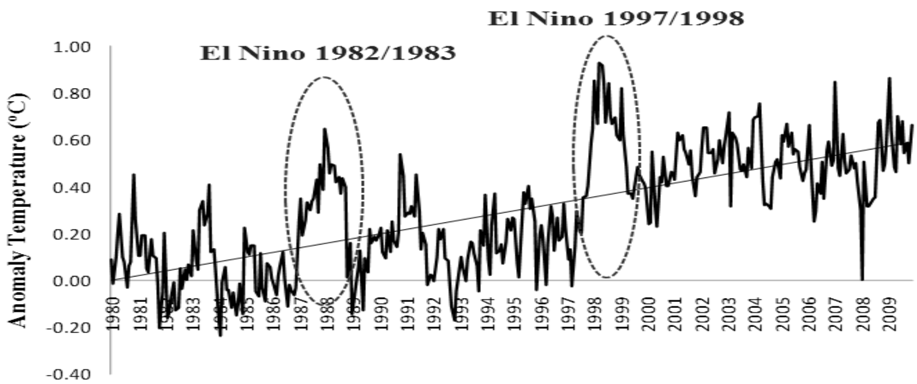



**Figure 4.** Anomaly Temperature (°C) in Asia and the Pacific regions (CRU-UK, 2010).

## 3. Risk Processing

Risk processing uses numerical modeling analysis combined with atmosphere and land simulation by NOAA and MODIS to detect hot spot area. The simulation does not consider ocean condition currently. For precise prediction, we propose the integrated model of atmosphere-land-ocean using Regional Environmental Simulator (RES) (Figure 5) which was developed by Hiroshima University (Yamashita *et al.,* 2007).

Furthermore, the simulation need be verified in the field with fire occurrence for accurate prediction. If the prediction cannot give accurate alerts for early warning system pre-fire, the users will not trust the warning for the control and

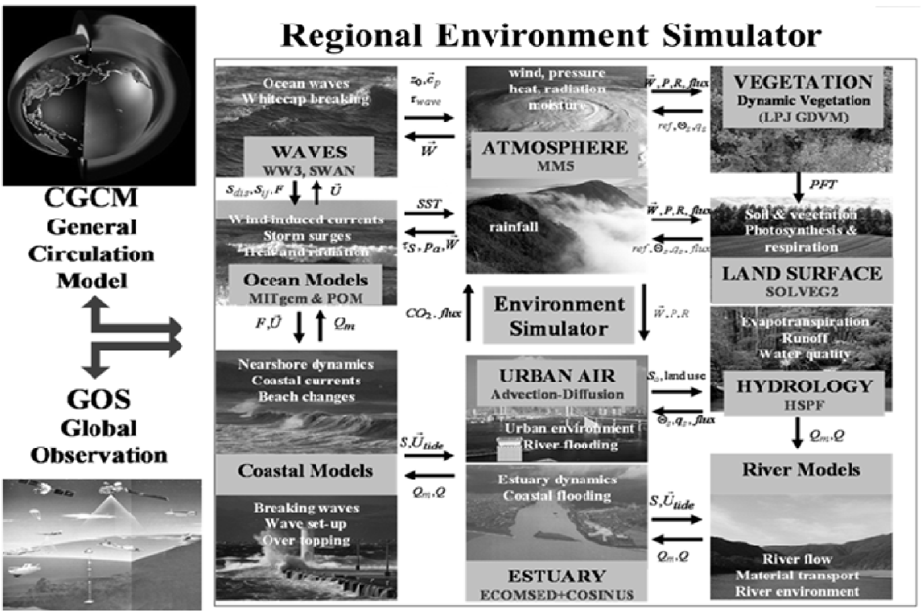



**Figure 5.** Regional Environmental Simulator (RES), Yamashita *et al*., 2007.

management. Thus, predictions and forecasts are critical points and need high qualification recruitment to simulate numerical modeling.

### 3.1. Space Technology Networks

The processing also needs application and networks sharing of space information products and services in fire disaster management, requiring the joint efforts from multi-stakeholders and information and communication technology (Figure 6).

Figure 6 shows that space technology has several stakeholders who contributed financially to decision making, and to set up facilities; while information and communication technology has 2 stakeholders who distributed information. Before space technology data can be easily understood by the public, the researcher should make interpretations based on observation data to try to simulate a prediction for alerting the early warning system (EWS). There are important activities to support accuracy and high performance for monitoring disaster risk reduction. If the prediction is not an accurate estimation, it will only create a low credibility source for any monitoring agency. The EWS cannot support the network system based on these sources. Therefore, it is necessary to develop and upgrade the skills of simulation technology for researchers, not only with considerations for meteorology and hydrological component but also with ocean interactions.

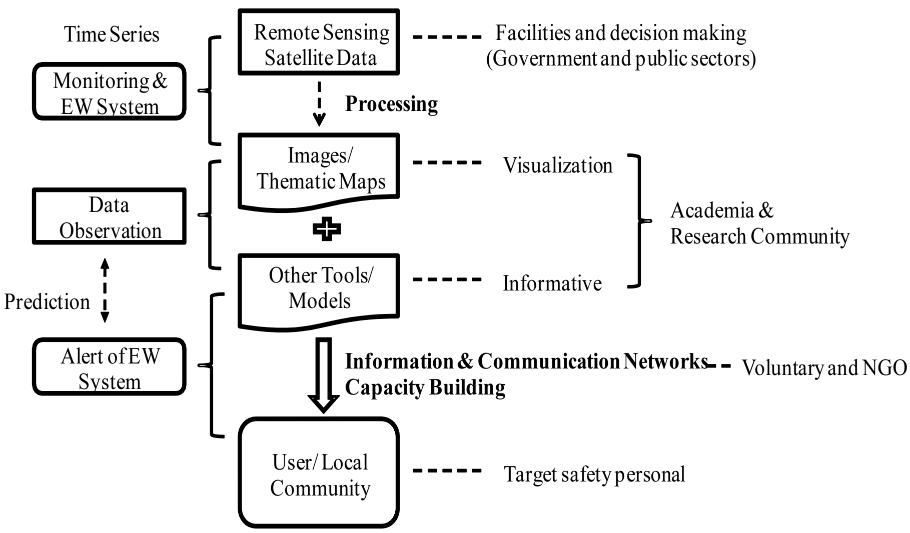



**Figure 6.** Sharing networks of space technology.

Furthermore, the sharing of networks should be supported by capacity building not only limited to the central government, but also extended to the local community. Quickly disseminating brainstorm knowledge, information for easy understanding, and visual images before disasters occur.

### 3.2. Space Information Products and Services for Fire Management

The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) has organized efforts to use space technology for disaster management under the Regional Space Application Programme for Sustainable Development in Asia and the Pacific (RESAP) in 2002. These activities contain broad technical, institutional, and policy issues related to enhanced utilization of products and services for effective disaster management. For implementation of these activities, there is a need to break down into more detail each country specific disasters, such as drought or fire.

The operational satellite images for fire disaster in Asia and the Pacific utilized different spatial, spectral and temporal resolutions which can be applied in different stages of fire management. However, the price of high and very high resolution satellite images is very expensive thus are difficult to order for LDCs and SIDs. Therefore the low and moderate satellite images should be developed together with precise simulation in the risk processing part.

## 4. Risk Information Transfer, Evaluation, and Reduction

The European Forest Institute (2010) introduced the integrated fire management (IFM) in Asia and the Pacific region with an integration into four pillars, i.e.: initiation, propagation, prescribed burning, and suppression fire. The IFM has three alert early warning system conditions, i.e.: pre-fire, during-fire, and post-fire. Pre-fire gives information about the potential fire due to fuel management analyses and how to prevent the fire events. During-fire monitors the extent of fires and to prepare evacuation for the users who are near the fire occurrence area. Post-fire contains database assessment and evaluation of the affected area, for example particulate matter and smoke. This condition is referred to as the next early warning system.

In early warning process, the risk information transfer, evaluation and reduction is needed to implement IFM for successful activities to prevent fire disasters at the local communities level. These activities aim to transfer information services from the control and management to users through decentralization and free access, by using easily understood and utilized packet information based on the communities knowledge (Figure 7). The packet information in this study consists of audio, audio-visual, e-learning, and more flexible access using e-mobile with short message service of fire information pre, during, and after fires. After that, local governments need to evaluate the risk information transfer and to make adjustment to fire evacuation procedure based on experiences in the field. Furthermore, the local government can prepare to reduce the fire disaster using mitigation and adaptation plans.

The risk information transfer, space technology has already been implemented in fire management using non-commercial

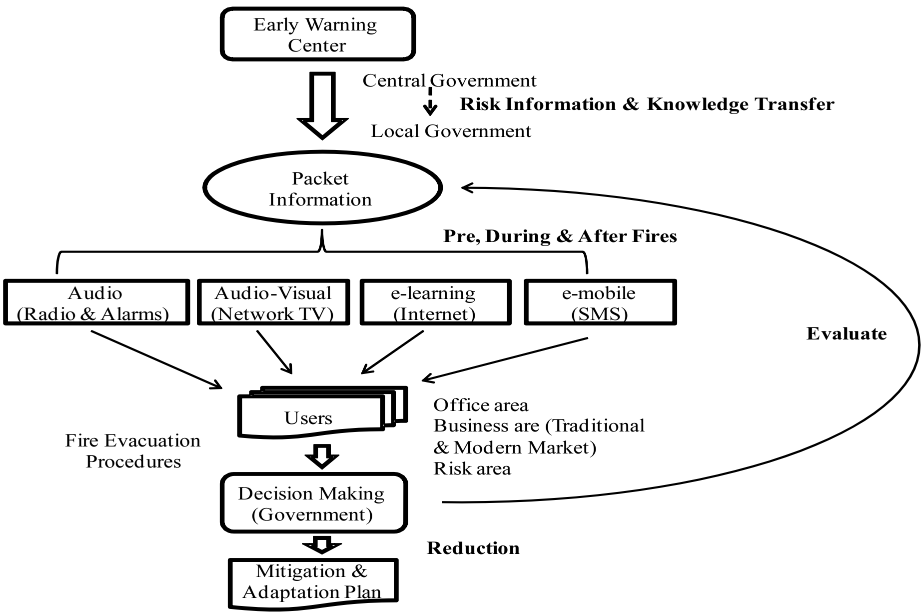



**Figure 7.** Network of Risk Information Transfer, Evaluate and Reduction.

and commercial products and services. However, for international and regional cooperation frameworks and mechanisms, especially for LDCs and SIDs, free and easy access non-commercial products and services is required.

Space information products and services in representative countries in Asia and the Pacific regions, are not particularly effective due to the largess of the forest fire and bushfire area and increase $CO_2$ emissions recent decades, especially in The Russian Federation, India, Australia, and Indonesia. Therefore space technology must be improved by utilizing technologies and mechanisms.

### 4.1. Non-Commercial Space Information Products and Services for Fire Management

Forest fire monitoring in many countries is conducted by UN-ISDR (United Nations-International Strategy for Disaster Reduction) standards with the information sent to Global Fire Monitoring Center (GFMC) which uploads the data on the world wide-web. However the satellite information products and services are not available for free. Only a few websites carry fire monitoring information. These sites are listed below.

**MODIS Rapid Response System Global Fire Maps** established since 2007 using Terra and Aqua satellite developed by NASA. MODIS fire data are available in various forms (e.g. interactive web mapper, Geography Information System (GIS), Google Earth, text files) through the Fire Information for Resource Management System (FIRMS) at the University of Maryland. The fire map is also combined with fire detection algorithm, Digital Elevation Model (DEM), and validation from ground check. The fire maps can be accessed on the website, http://rapidfire.sci.gsfc.nasa.gov/firemaps/.

To promote global fire EW system and fire management for international cooperation, the Global Fire Monitoring Center (GFMC) was established by the Food and Agriculture Organization (FAO, 2006) using MODIS Rapid Response System and the GOFC/ GOLD (Global Observation of Forest and Land Cover Dynamic) fire mapping and monitoring network which is a joint effort with IGOS (International Global Observing Strategy) and UNISDR (United Nations International Strategy for Disaster Reduction).

For Asian cases, the fire map was developed by AIT (Asian Institute Technology) from 2006 using MODIS Fire Information System (MODIS-FIS) based on MODIS Active Fire Product (MOD14) Production Code, version 4.3.2. The system developed 4 stages for effective understanding of fire occurrence and fire management, i.e. MODIS fire product generation system, MODIS fire visualization system, MODIS fire database and statistical analysis, and MODIS fire data validation system (Phonekeo *et al.,* 2006).

**Sentinel Asia** Wildfire Working Group provides hotspot and wildfire monitoring in Asia and the Pacific since 2007 with applied MODIS satellite using MOD14 algorithm. The processing was built by the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia; AIT in Thailand; Center for Remote Imaging, Sensing and Processing (CRISP) in Singapore; The University of Tokyo, Hokkaido University, Keio University in Japan; and MTSAT meteorology satellite from JAXA (Japan Aerospace Exploration Agency). After that, the satellite output is processed with other software and information such as DEM, land cover and population, and fire ground check for validation. Furthermore, Sentinel Asia enhanced their abilities and technical capabilities by cooperating with the International bodies (UN ESCAP, UN OOSA, and ASEAN) and the disaster reduction community (Asian Disaster Reduction Center (ADRC)). The fire map for near real time monitoring can be accessed on the website http://arrs.adrc.asia/adrc/MyMap/HotSpot_MTSAT/index.jsp.

### 4.2. Evaluation and Reduction of the Limitation of Previous IFM

The integrated fire management implementation based on European Forest Institute (2010) has severe difficulties such as the problem of peat fire due to ignite charcoal, lack of technology and human resources, information gap with local communities, and lacks a clear strategy. Therefore the new IFM needs other technologies and information to support the effective fire prevention not only based on satellite products and services, but also based on measurements using fire observation equipment for underground fire detection, in addition to setting up local policy and institutions, enhancing capacity building, and setting up financing mechanism for sharing.

#### 4.2.1. Design fire observation equipment and AWS for underground fire detect

To detect smoke from underground fires for the early warning, the fire watch technology (2008) is promoted to solve the peat fire problem. The technology covers early detection of forest and bush fire at day or night, drawing on six years of experience by the German government and private sector, and is known as Fire Watch technology. This technology has been adopted by European countries such as Estonia, Greece, Czech Republic and Portugal. Furthermore, it was expanded to Mexico and Australia to prevent bushfires.

The technology was developed in three different parts, i.e.: IQ wireless and sensor systems, installation-maintenance-service, and operator. IQ wireless and sensor systems provide optical sensor system with high resolution (10 m x 10 m in 10 km distance) and increasing night sensitivity in NIR wave for 360º rotation in 8 minutes. This sensor was set up together with automatic weather system (AWS) at high elevation using towers or the top of hilly areas. The installation, maintenance and services are handled by a company for guaranteed quality and response. The operator hires people who know the area and are able to decide when to order the alert of the warning system.

#### 4.2.2. Set up local policy and institutional arrangement for IFM

To increase information for data users, the quick response of operational policy and institutional arrangement with local government is needed to develop and under coordination a particular or special organization especially for disaster management in general and especially for fire management.

This special organization for regional cooperation is required to improve sharing of space technology, information products and services under the UN-ESCAP disaster relief policy framework. After that, the organization plans initiatives to promote regional cooperative mechanism for national and local service providers and fire managers for identification and final services.

To enhance IFM, Australia has already renewed the policy and institutional arrangement after the Black Saturday Bushfire, in February 2009. The new systems included new technology and education promoting with new course of fire behavior and ecology. This action is necessary to be followed by the other countries such as Russia Federation, India, and Indonesia to reduce annual fire occurrence.

#### 4.2.3. Enhance capacity building

Strengthened capacity building for data users is needed to give as much information as possible about the fire integrated management and how to read and interpret data products for reducing fire disaster impact.

To build networking on all levels both regional and local, it is important to increase accessibility and transmissions, sharing space technology, information products and services, especially communication networking after the fire disaster.

These activities, especially for fire disasters are already undertaken by international bodies notably GFMC together with UN-ISDR. Yet these activities are still limited and cannot cover large areas, therefore further financial support from established mechanisms, for example, through the United Nations-Office for the Coordination Humanitarian Affairs (OCHA) is needed.

#### 4.2.4. Set up financing mechanism for sharing

Financial support should not only come from international funds, but also from regional groups and private agencies, it is necessary for developing countries and especially the least developed countries with financial pressures, to obtain help and assist in developing the integrated fire management system.

Otherwise, assistance can also in the form of free web-based products and services, the provision of satellite information for humanitarian assistance, and the enhancement of local capacity building with technical training and guidance.

## 5. Regional and International Cooperation

The new policy and institutional arrangement should be implemented not only at the national level but also at the local level with the aim of enhancing capacity building for local control and management. At the national level, partnership collaboration with the Regional and International organization is needed for sharing space information products and services.

For a global strategy, the researchers from UN OOSA (United Nations Office for Outer Space Affairs), CNES (Center National d'Etudes Spatiales), and DLR (German Aerospace Center) promotes the complex coordination of the integrated risk reduction. These activities link the regional networks and international bodies including framework and task forces, coordinating entity and national vocal point, national institutions, and the user community.

In Asian, China also promotes IFM with consideration of the complexity of disaster systems integrated three-dimensionally in horizontal harmonization, vertical harmonization, and institutional harmonization. The horizontal harmonization means harmonization among different government departments and other disaster reduction organization. The vertical harmonization means harmonization at all levels of governance with the local governments focused on the disaster area. While institutional harmonization means harmonization among all kinds of policies related to disaster reduction (Shi *et al.,* 2007).

In this study, regional and international cooperation filters from national governments, to provincial councils and down to

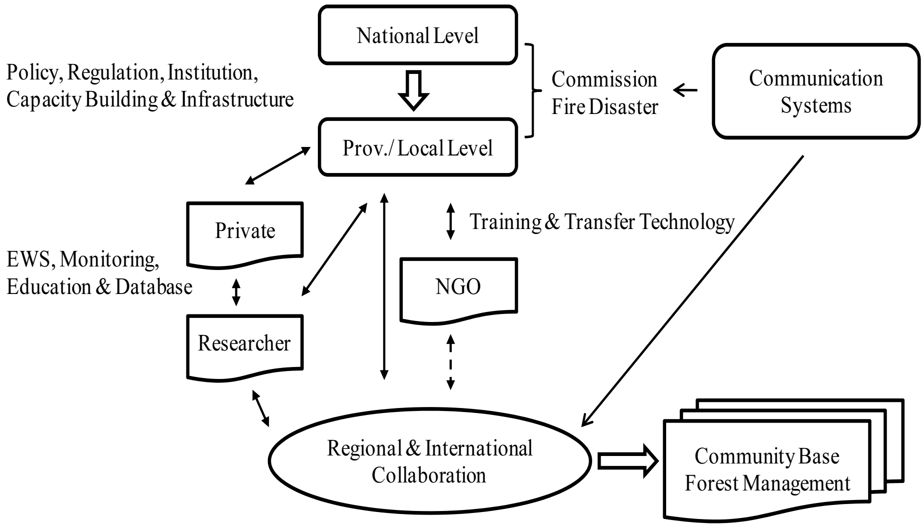



**Figure 8.** Networks of the National, local, regional and international cooperation.

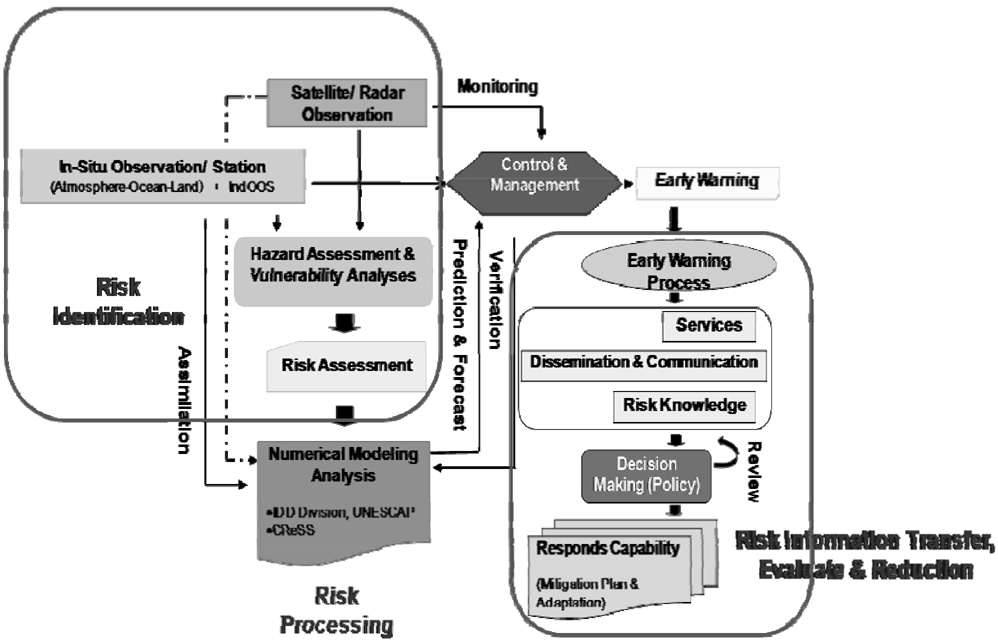



**Figure 9.** The framework of IFM in Asia and the Pacific.

local authority fire prevention controls. These bodies must collaborate with the private sector, NGO, and researchers. The collaboration framework is presented in Figure 8.

The complex framework of integrated fire management based on effective and accurate prediction using space information products and services in Asia and the Pacific region is presented in Figure 9.

## 6. Concluding Remarks

Risk identification requires the sharing of satellite/radar data and historical observation data including the interaction of atmosphere, land, and ocean data to establish FWI (Fire Weather Index) and mapping for risk assessments in fire disaster prone areas of countries in the Asia and Pacific region.

Risk processing involves numerical modeling analysis, application, networks sharing of space information products and services for fire disaster management and requires the joint efforts of multi-stakeholders in addition to information and communication technology.

Risk information transfer introduced the integrated fire management system (IFM) in Asia and the Pacific region with three alert early warning system conditions, i.e.: pre-fire, during-fire, and post-fire. These IFM also free and easy access to non-commercial space information products and services for fire management for promoting international and regional cooperation especially for LDCs and SIDs. Risk evaluation and reduction investigates severe difficulties and other technologies supported for effective IFM. The last part of the framework aims to build regional and international cooperation with local or national governments or authority agencies.

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